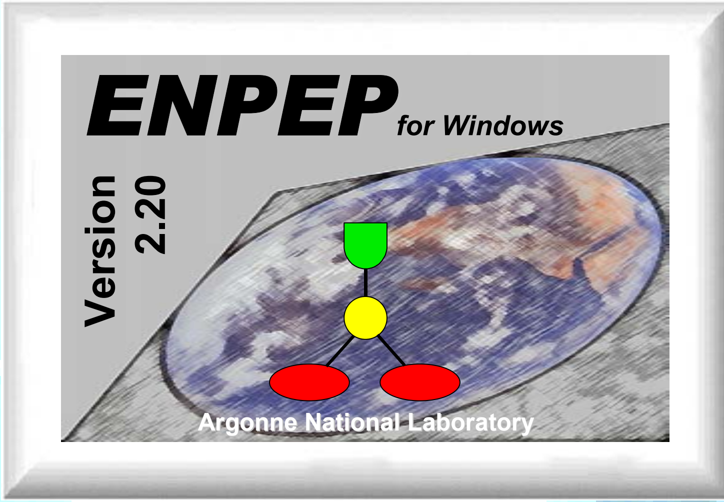

Overview of the Energy and Power Evaluation Program (ENPEP)

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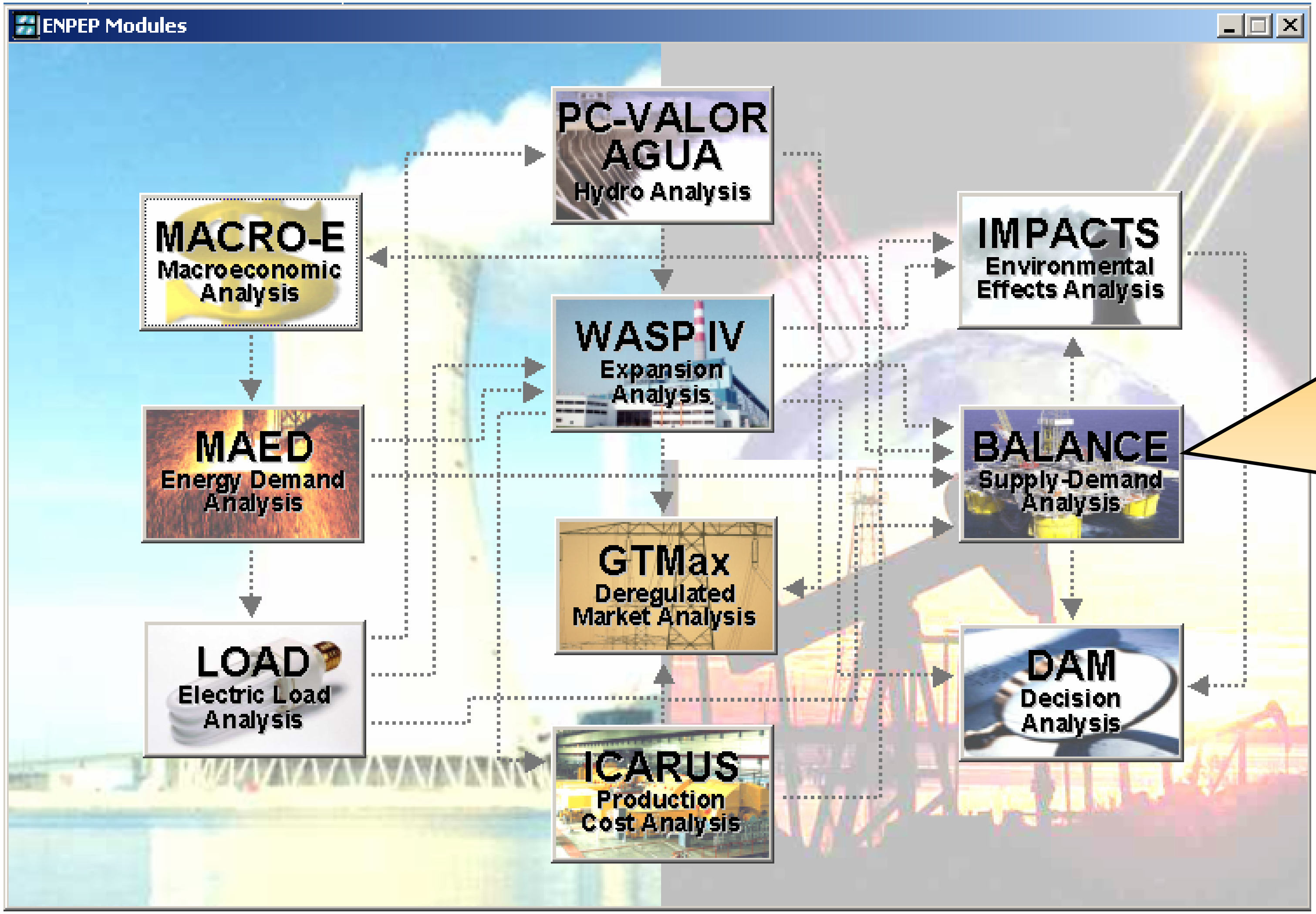
Argonne National Laboratory is a
U.S. Department of Energy research center
operated by the University of Chicago.

The Energy and Power Evaluation Program (ENPEP) Consists of 10 Integrated Analysis Tools

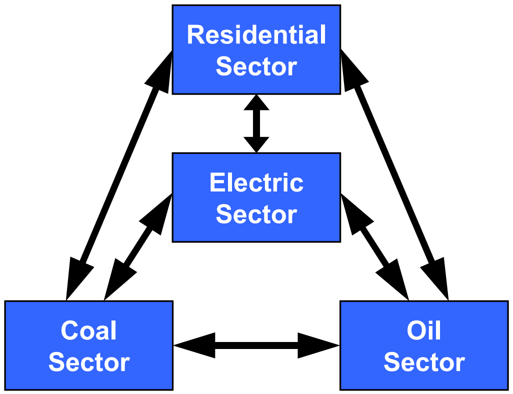


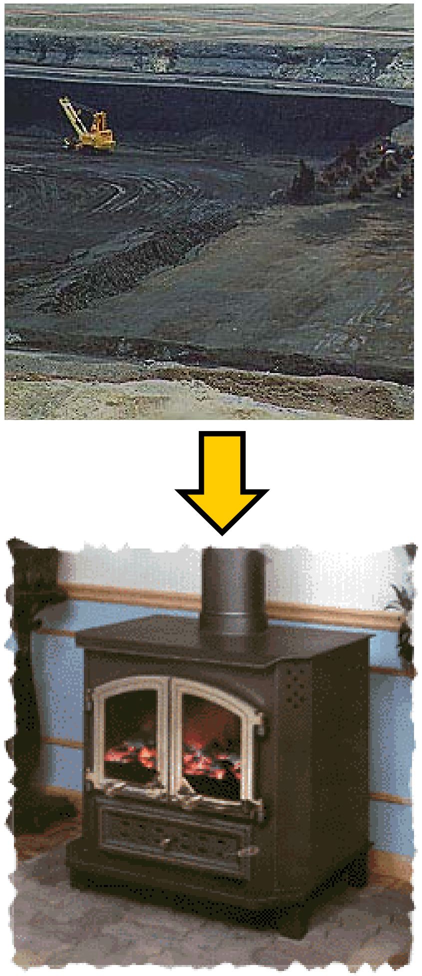
The rest of this presentation will focus on the BALANCE module.

Separate presentations are available for each of the other ENPEP modules.

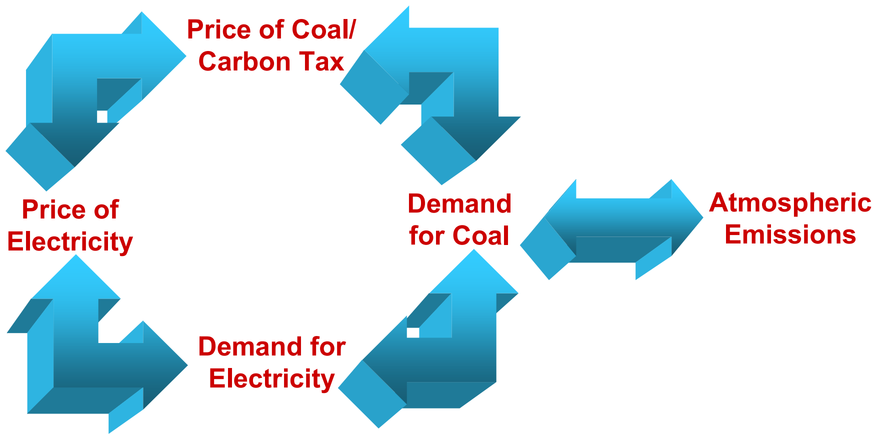
BALANCE is Designed to Analyze the Entire Energy System in an Integrated Framework

- Reveal cross-sectoral effects; provide structure for consistent energy "planning" program





- Integrated framework allows evaluation of feedback effects

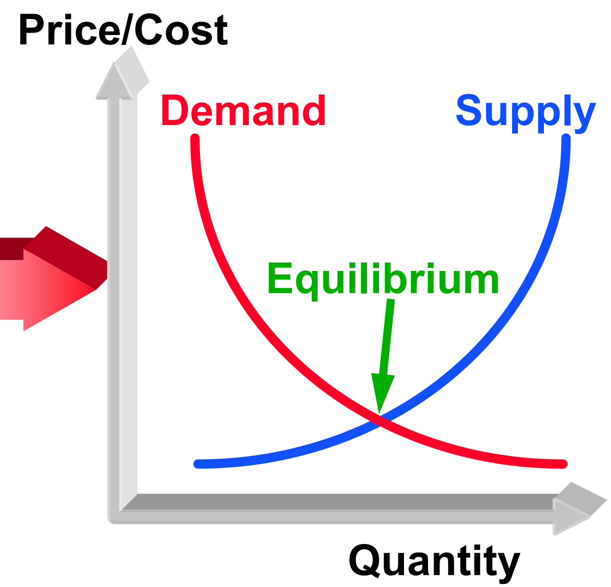


BALANCE Determines the Equilibrium Supply/Demand Balance of the Energy System

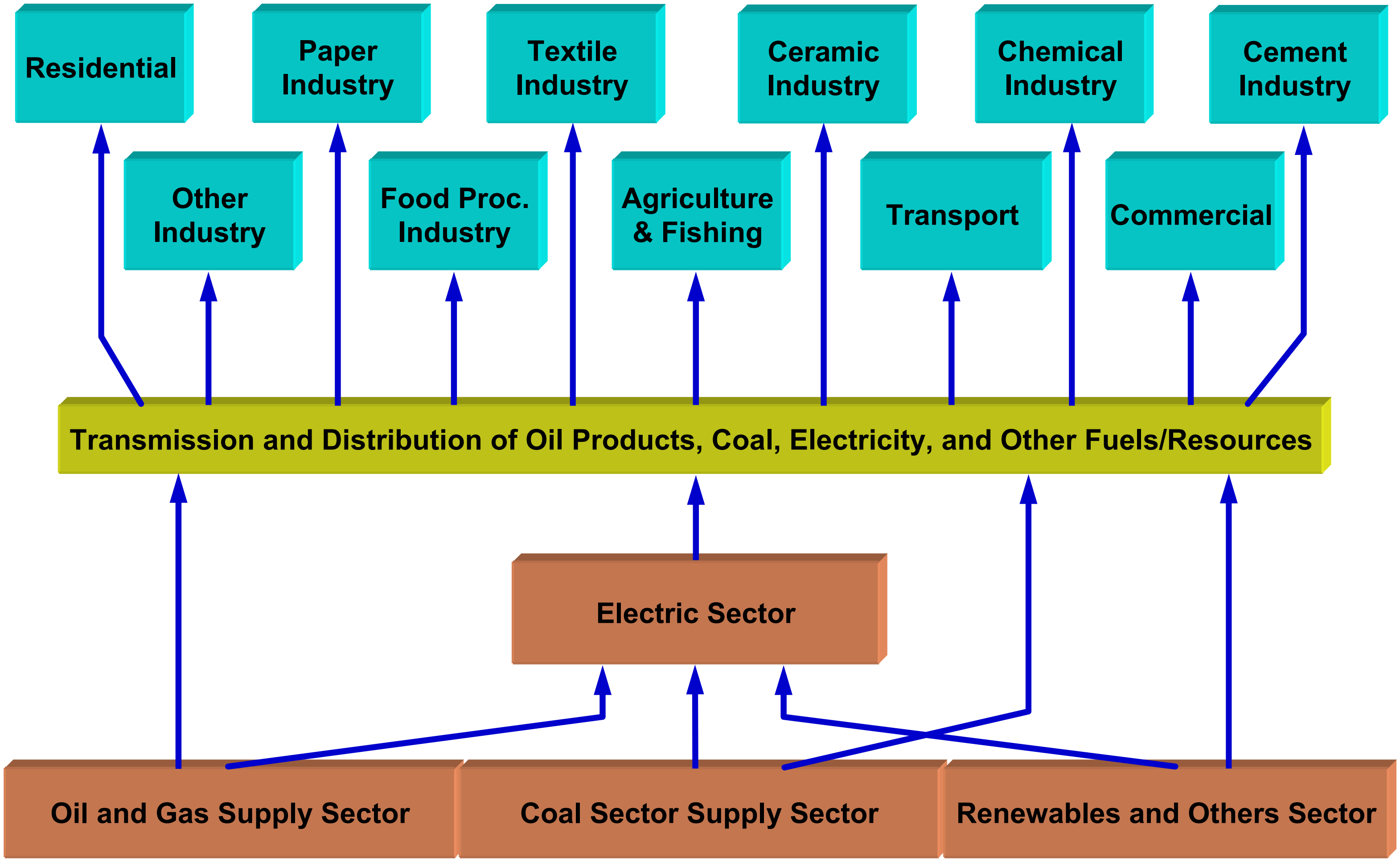
INPUT

- Energy system structure
- Base year energy flows and prices
- Energy demand growth projections
- Technical and policy constraints

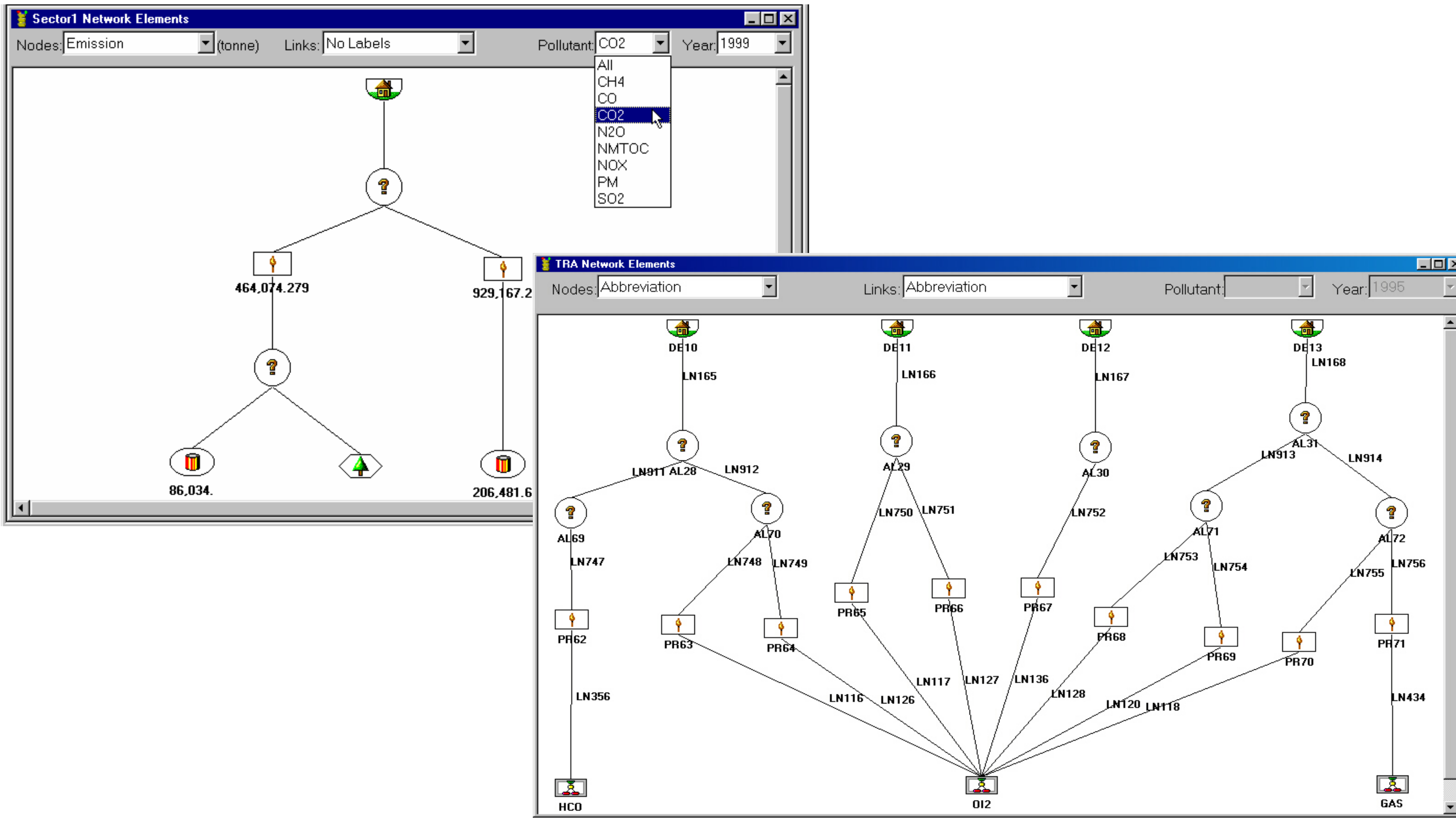
OUTPUT



BALANCE Uses an Energy Network to Simulate Energy Markets

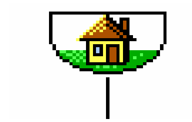


Using *Nodes* and *Links*, Each Sector is Modeled Differently Depending on Data Availability and Type of Issue Analyzed

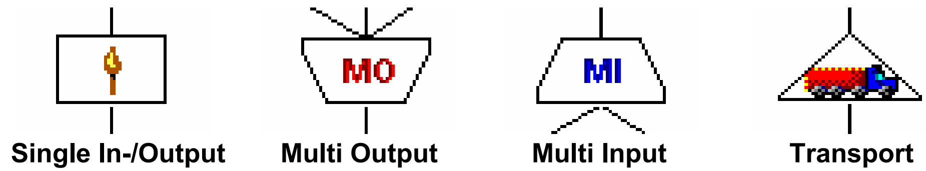


The Following Node Types are Available to Model Different Energy Activities

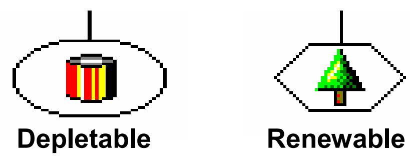
- **Demand**



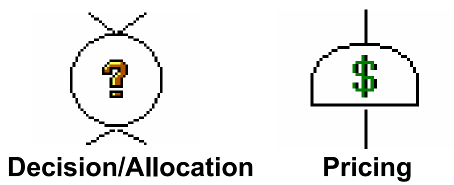
- **Conversion Processes**



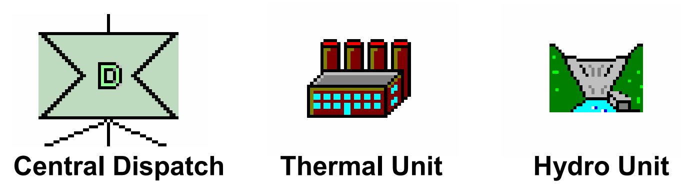
- **Resource Processes**



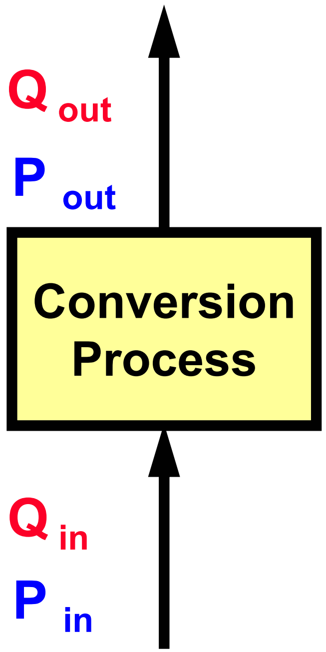
- **Economic Processes**



- **Electricity Dispatch and Thermal and Hydro Units**



Nodes Are a Series of Simple Sub-Models, Each With a Set of Quantity and Price Equations



- **$\text{Quantity}_{\text{output}} = f(\text{Quantity}_{\text{input}})$**
  - Example conversion process

    $Q_{out} = Q_{in} \times \gamma$

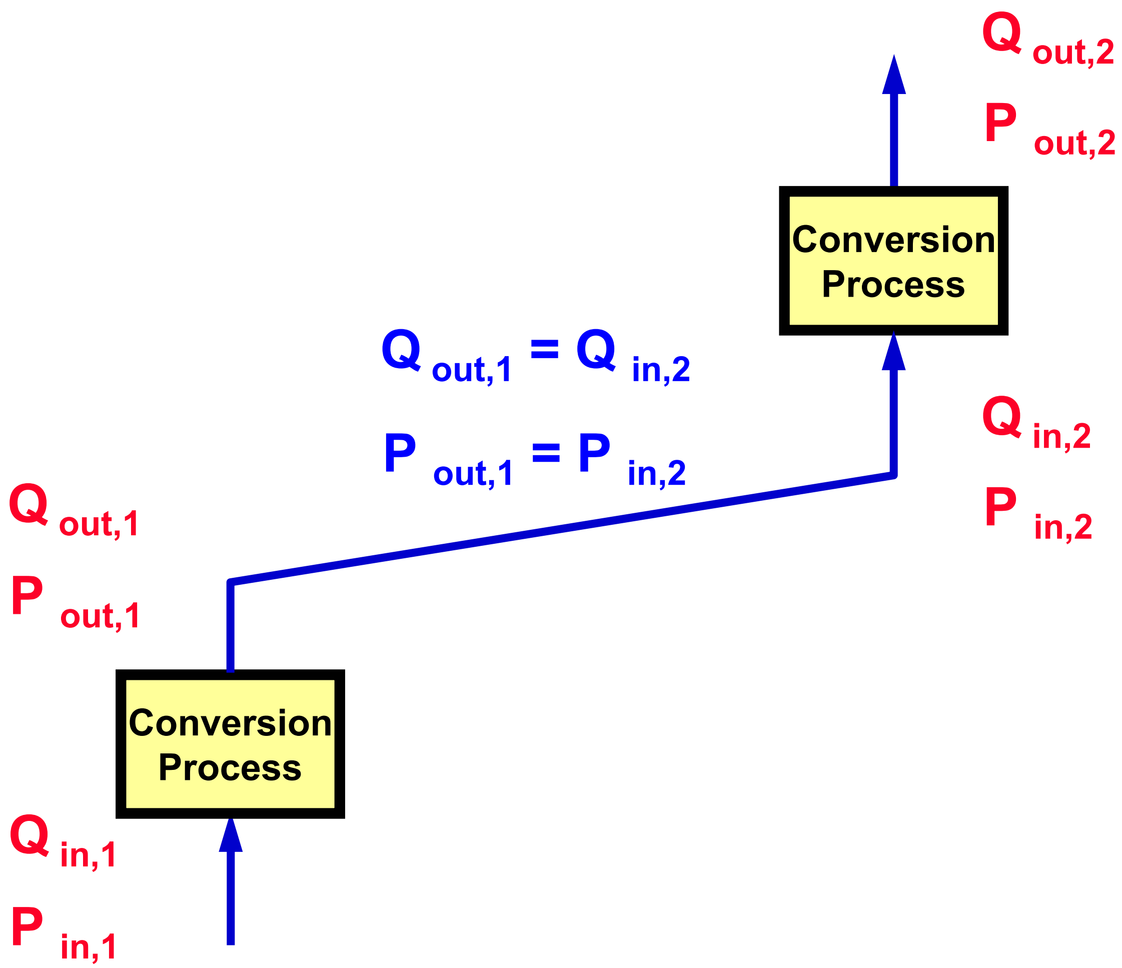
    γ: conversion efficiency

- **$\text{Price}_{\text{output}} = f(\text{Price}_{\text{input}})$**
  - Example conversion process

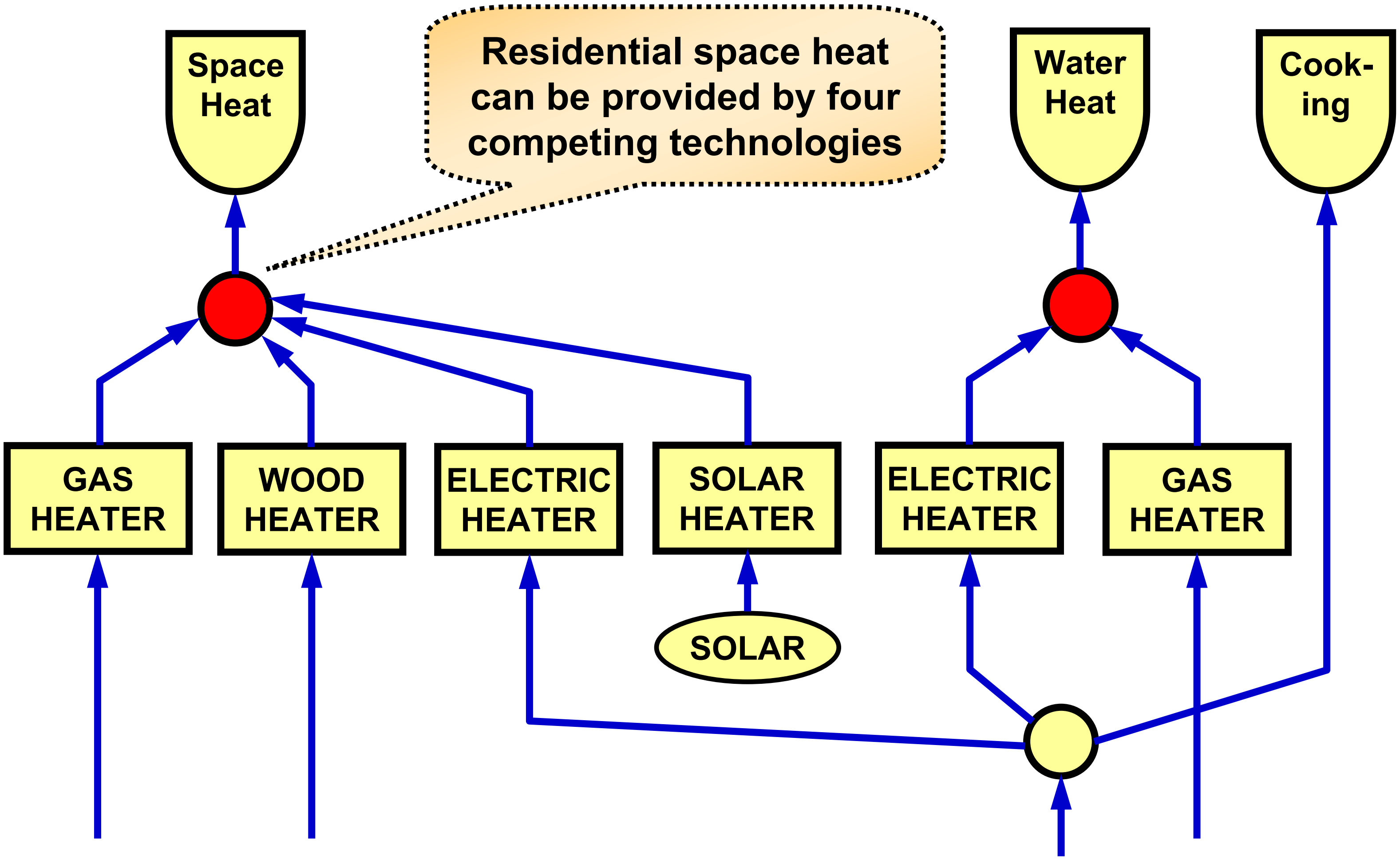
    Revenue = Cost

    $Q_{out} \times P_{out} = Q_{in} \times P_{in} + \text{O\&M} + \text{Capital Recovery}$

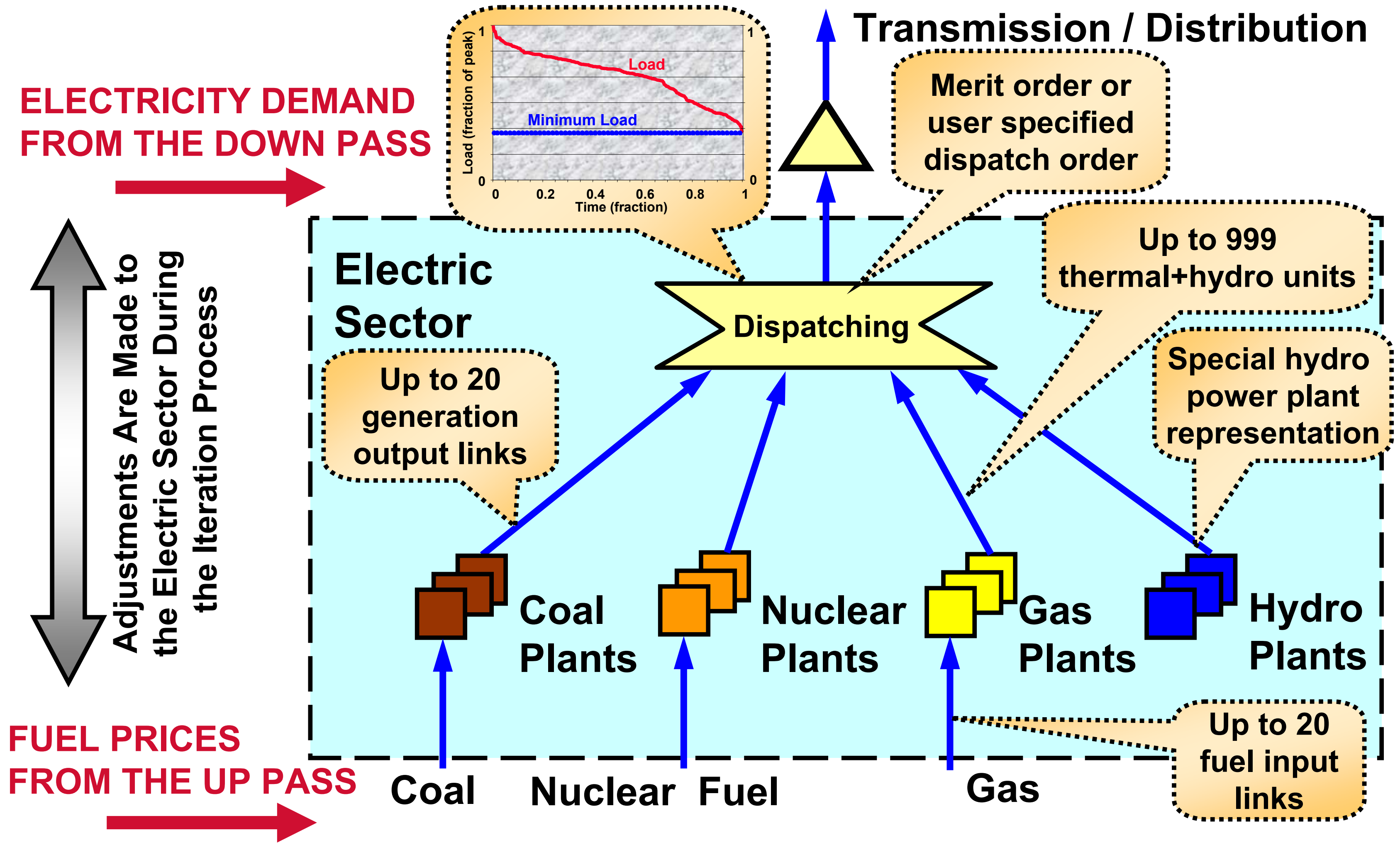
The Links Connect the Nodes and Pass Information from One Node to Another



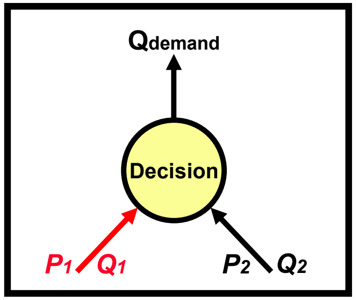
At the Decision Nodes, Fuels and Technologies Compete for Future Market Shares



The Electricity Dispatch Node Handles the Electric Sector in a Special Way

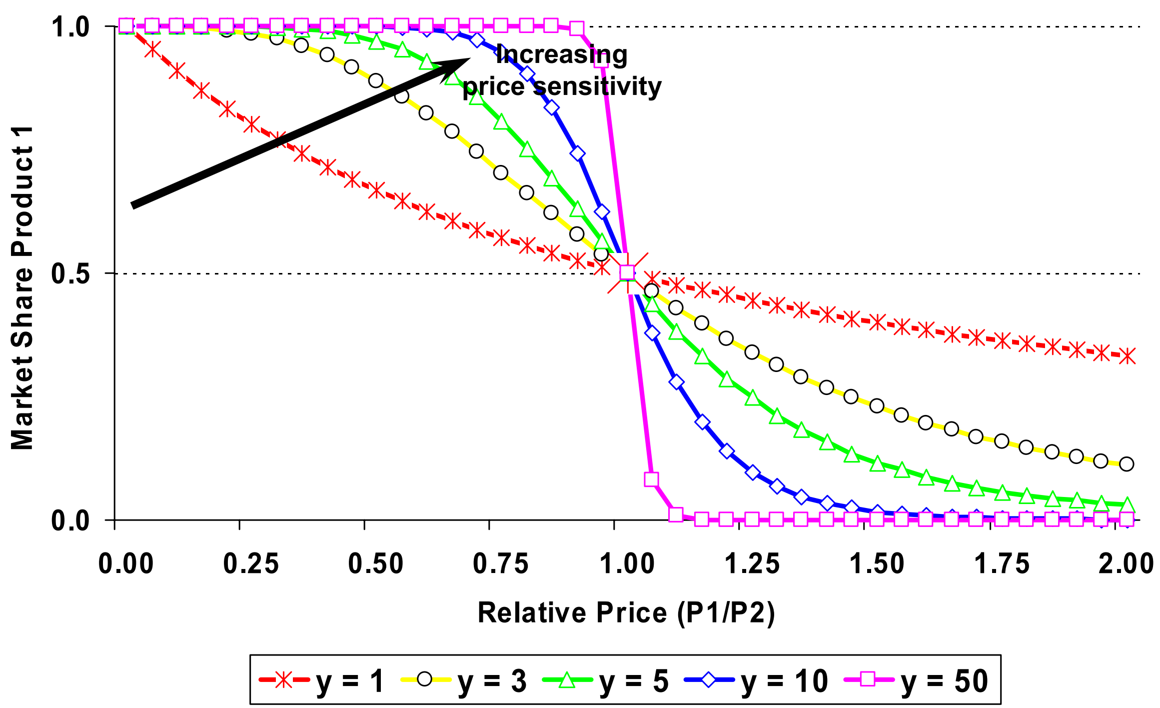


BALANCE Uses a Logit-Function to Estimate Market Shares of Competing Commodities at the Decision Node



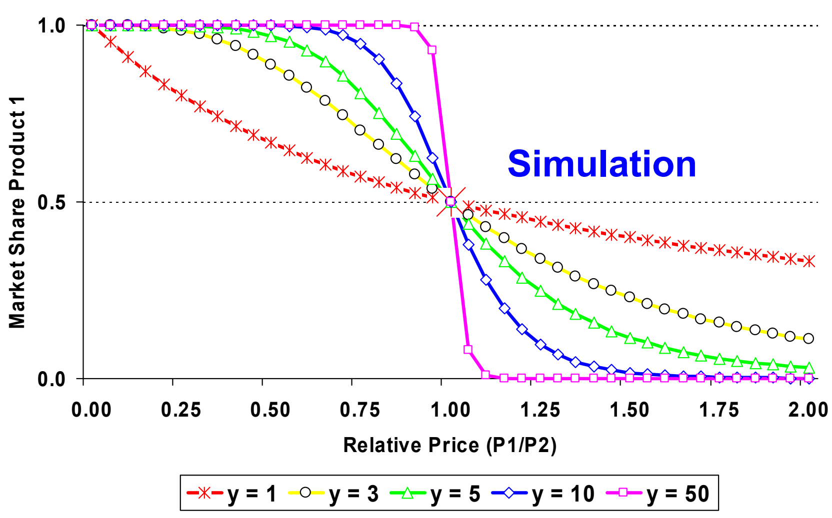
$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left[\frac{1}{P_1 \times PM_1}\right]^{\gamma}}{\left[\frac{1}{P_1 \times PM_1}\right]^{\gamma} + \left[\frac{1}{P_2 \times PM_2}\right]^{\gamma}}$$

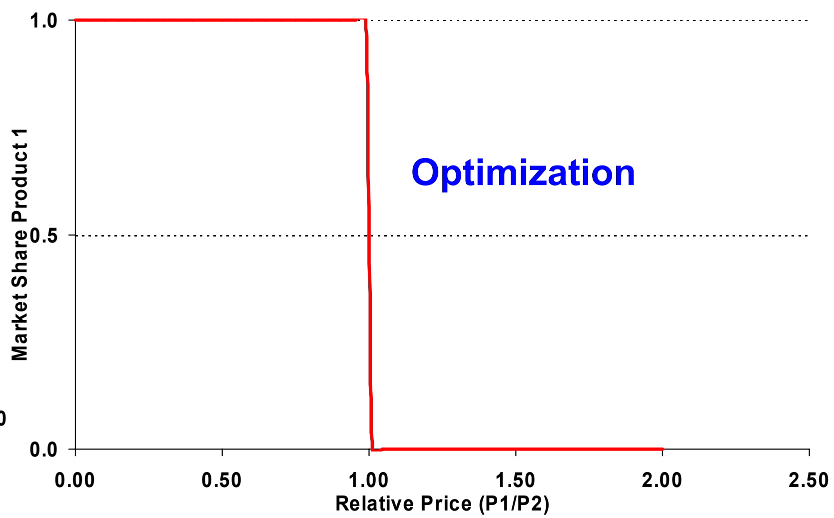
- γ price sensitivity for this decision process
- MS: market share
- P: price
- PM: premium multiplier
- Q: quantity



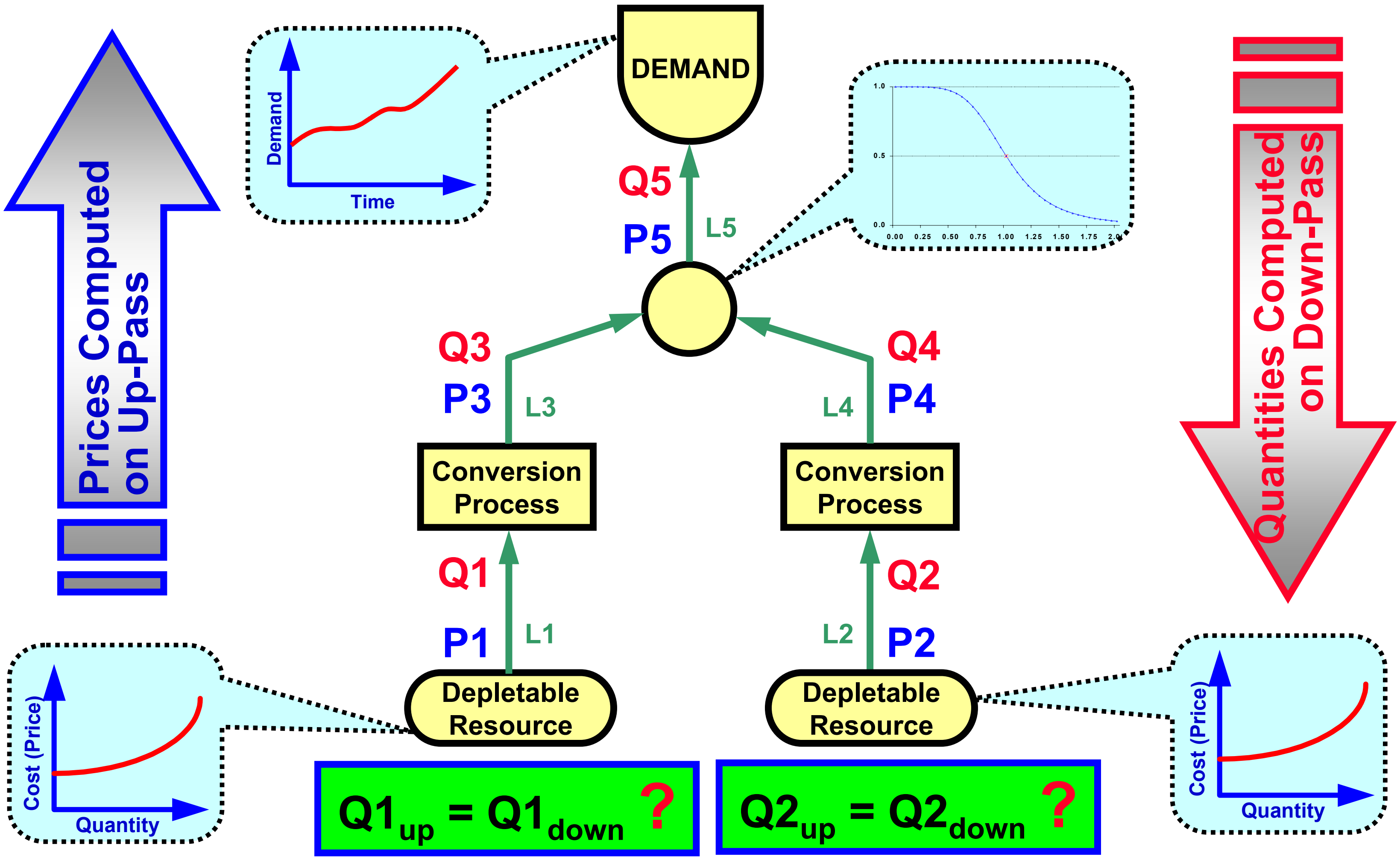
The BALANCE Nonlinear Equilibrium Algorithm is Based on Decentralized Decision Making

- Market share calculation assumes "ideal market" subject to government policies, fuel availability, and market constraints
- A lag factor accounts for delays in capital stock turnover
- The result is a nonlinear, market-based equilibrium solution within policy constraints, not a simple, linear optimization
- No single person or organization controls all energy prices and decisions on energy use
- All decision makers optimize their energy choices based on their own needs and desires





BALANCE Uses an Up/Down Pass Sequence and the Jacobi Iterative Technique to Determine the Market Clearing Prices and Quantities (Market Equilibrium)

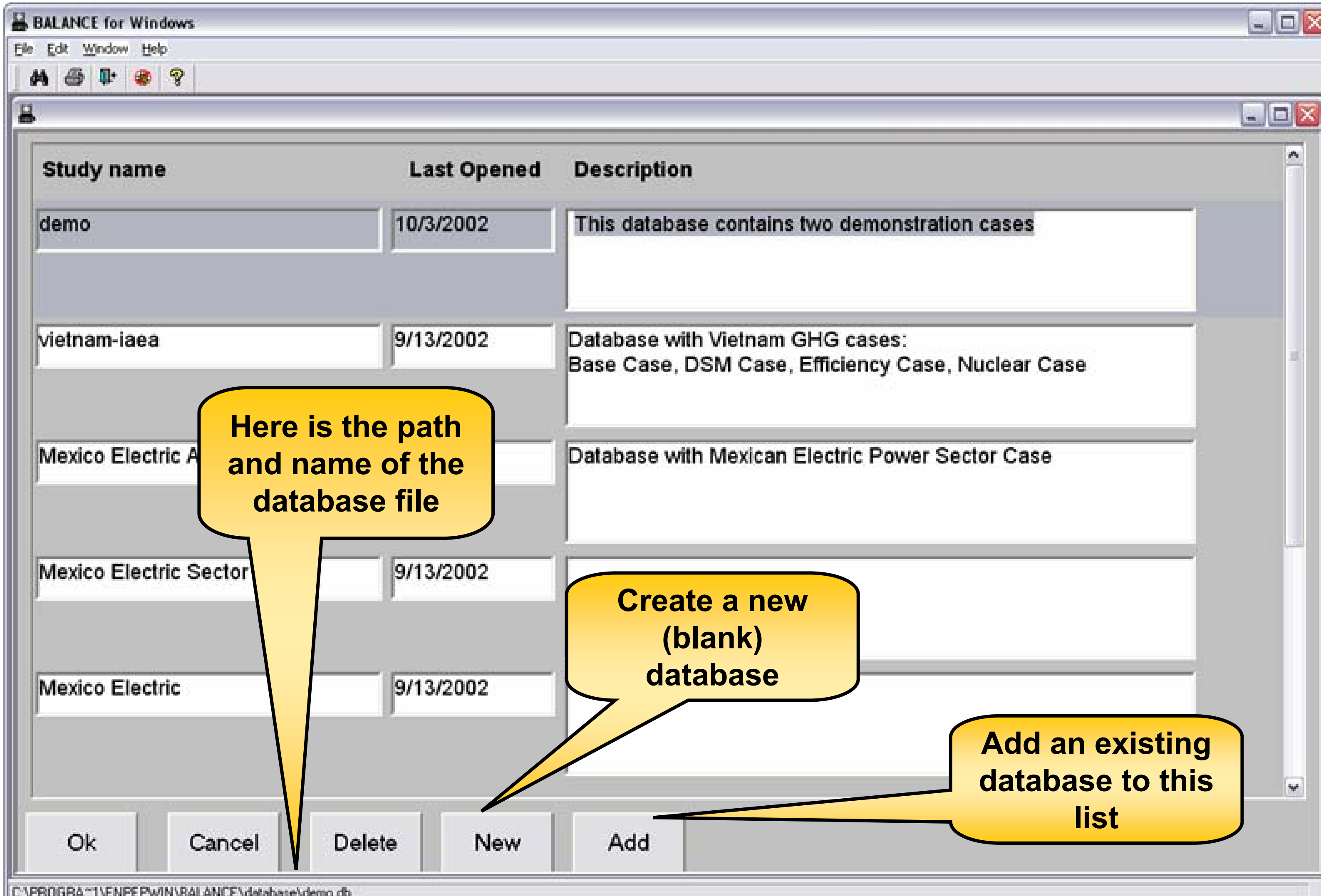


The Up-Pass and Down-Pass Sequences Are Repeated Until Convergence Has Been Achieved

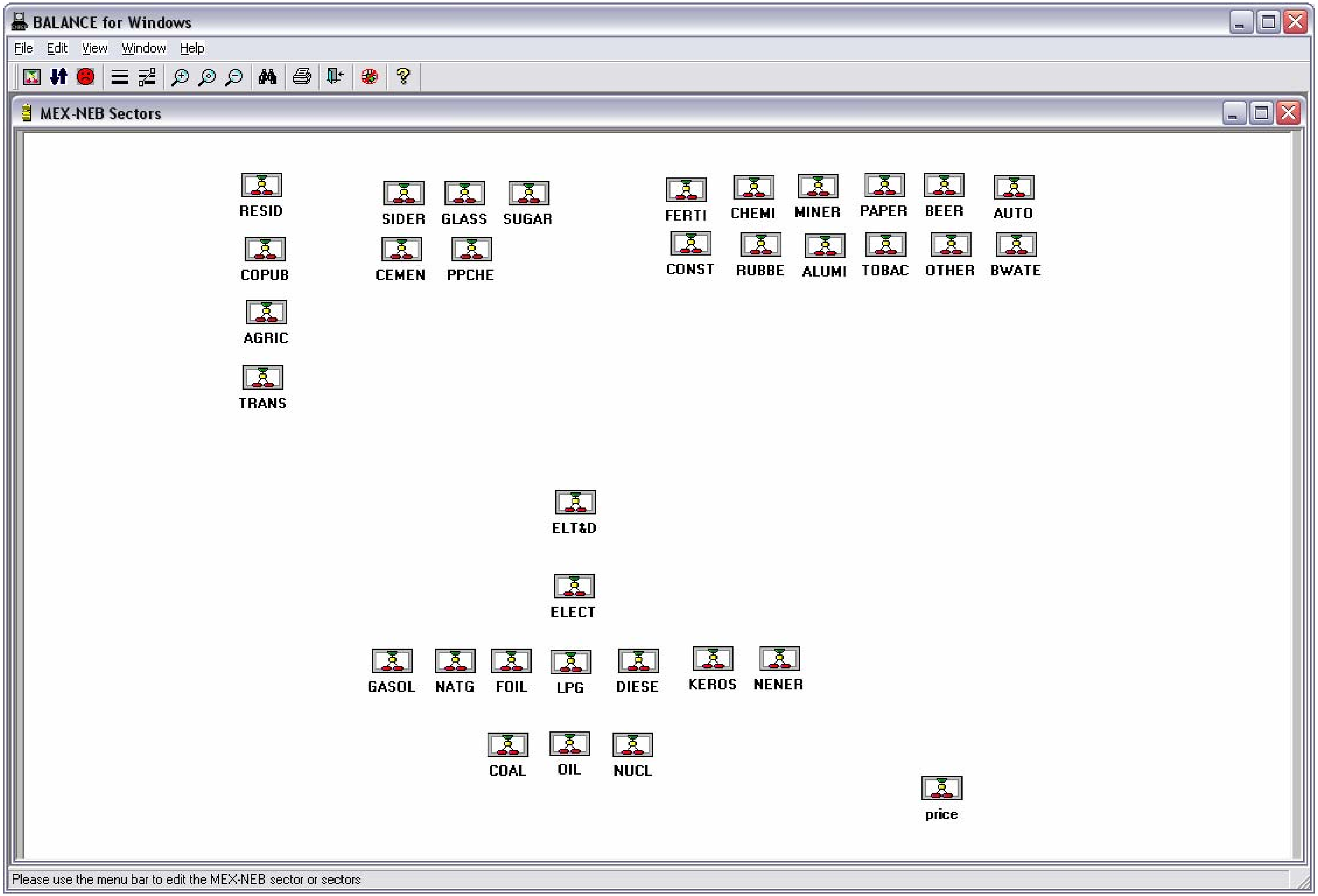
CONVERGENCE IS ACHIEVED WHEN:

- **Q1 (down) = Q1 (up) +/- Tolerance Level**
- **Q2 (down) = Q2 (up) +/- Tolerance Level**
- **The final result is a converged solution**
- **The solution is in equilibrium across the whole network**

Each Case Study Can be Stored in a Different Database

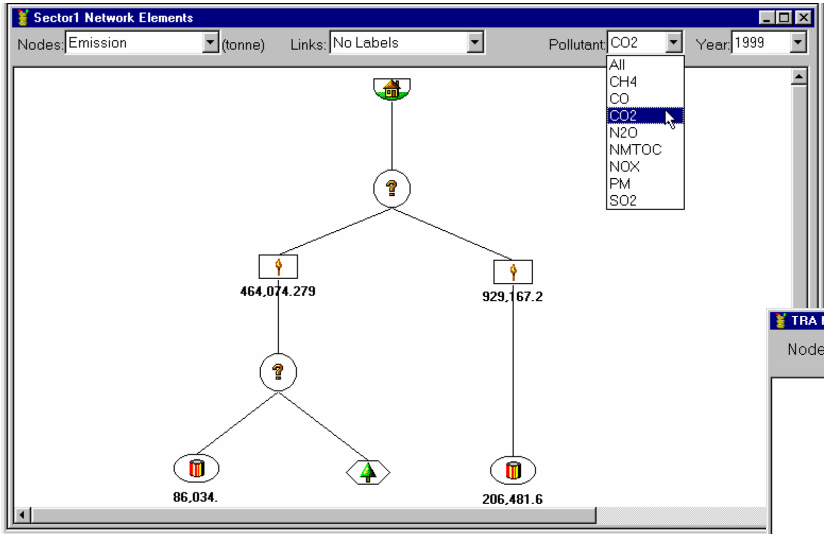


The First Step in Developing an ENPEP Network is to Define the Sectors Included in Your System

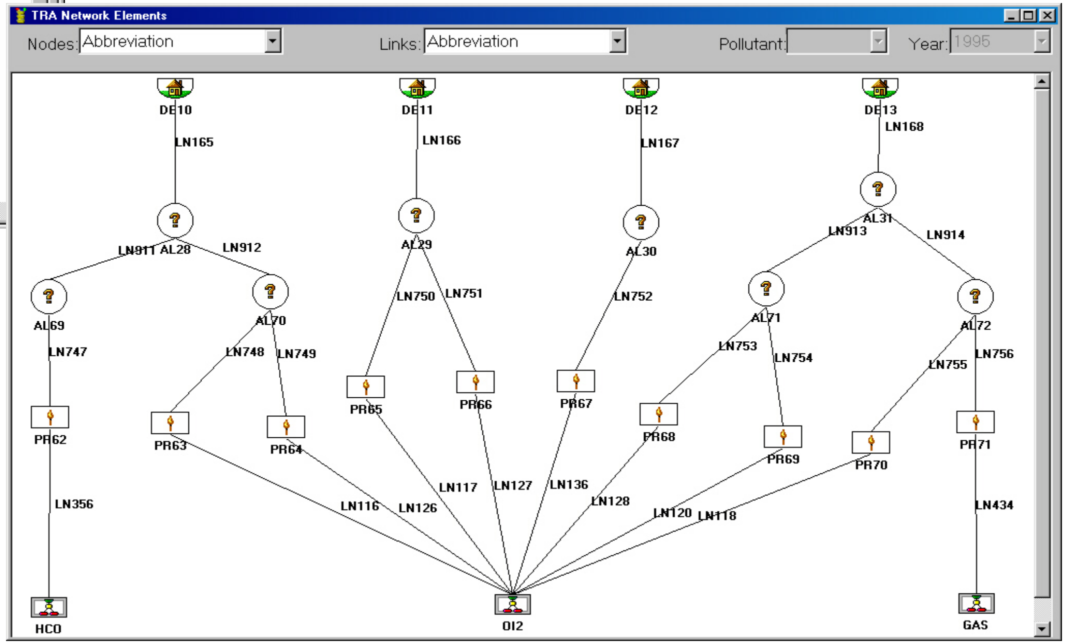


Each Sector is Modeled Differently Depending on Data Availability and Type of Issue Analyzed

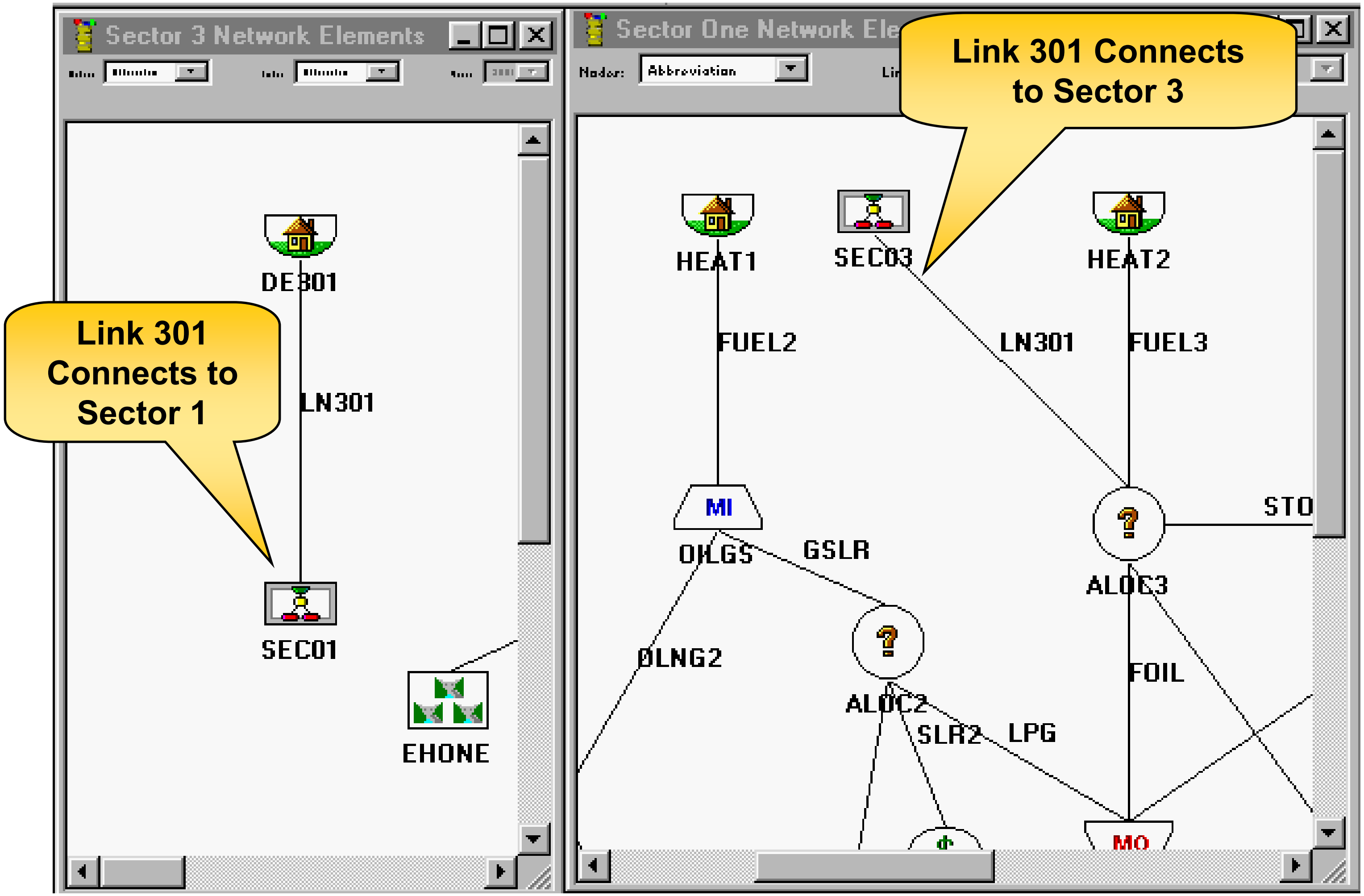
Simple Sector



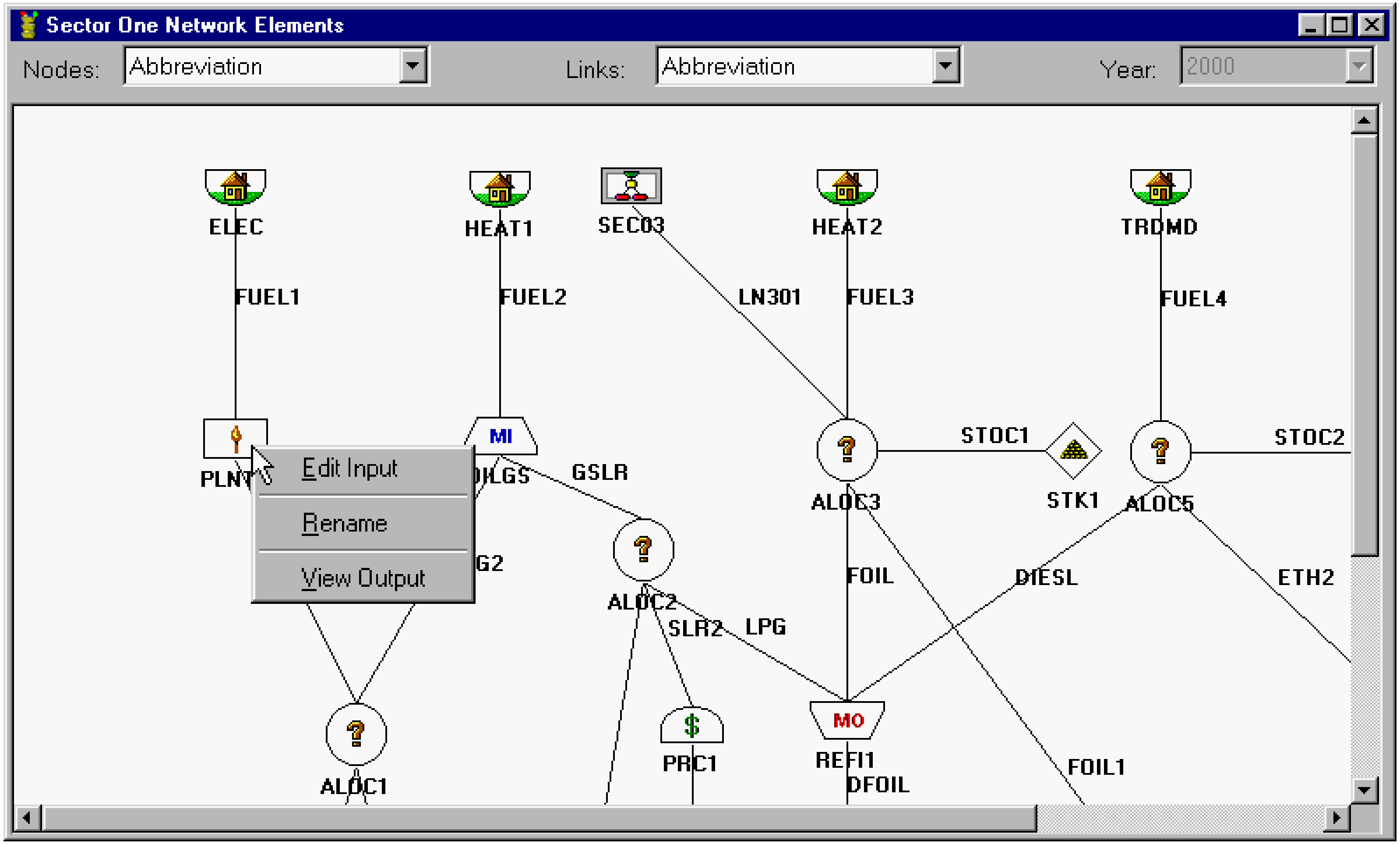
More Complex Sector



Inter-Sectoral Links Can Connect Energy Networks of Different Sectors

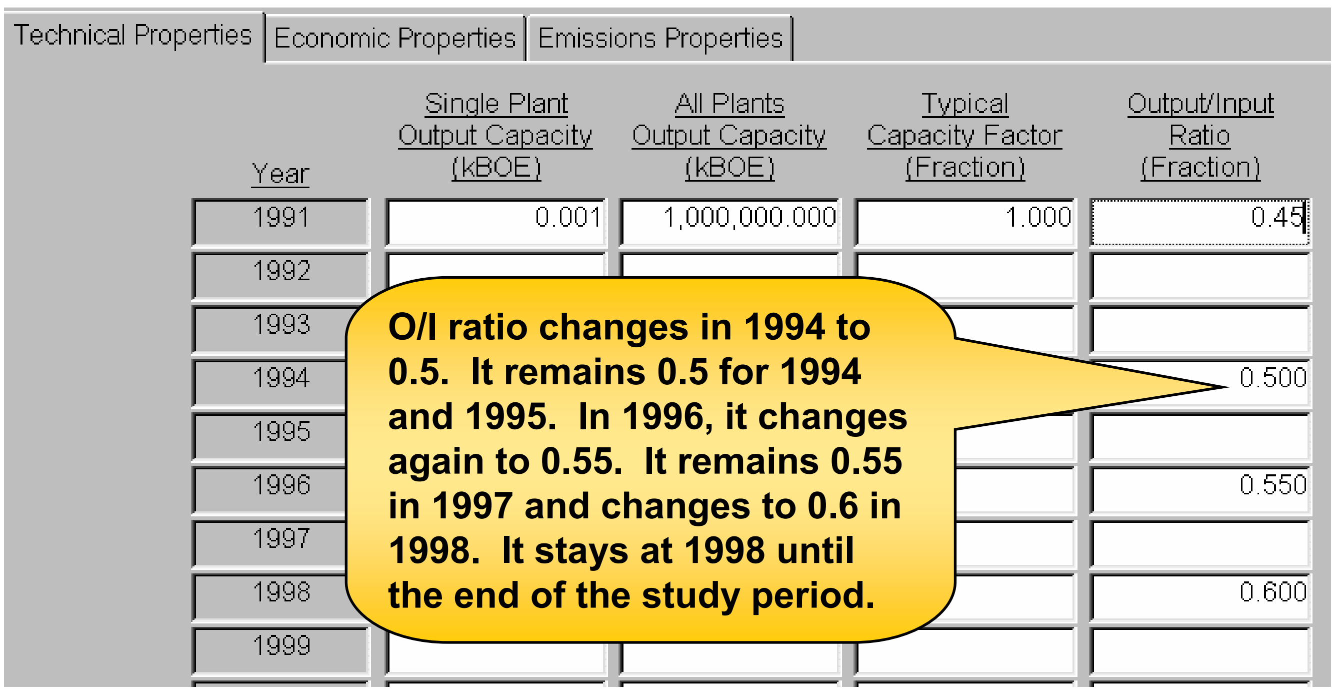


All Network Elements Can Be Accessed Using the Standardized Simple Menu

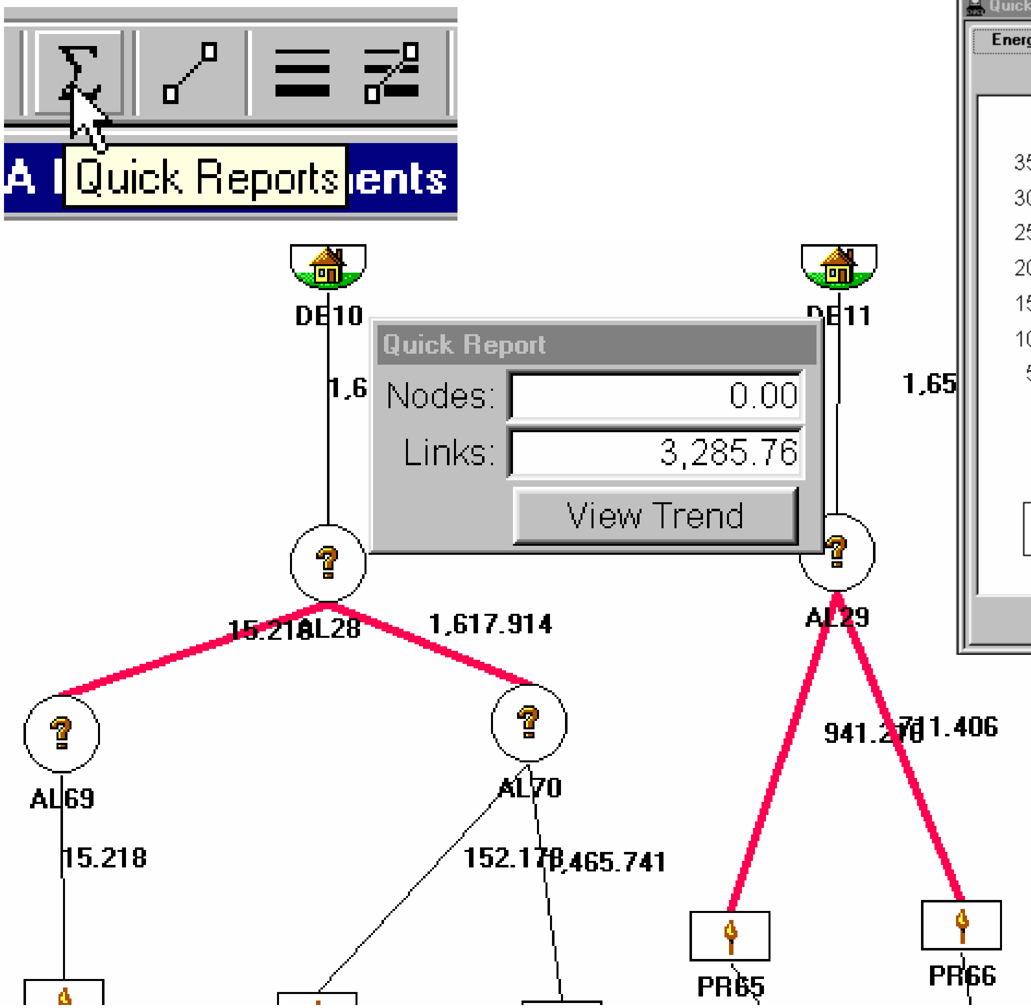


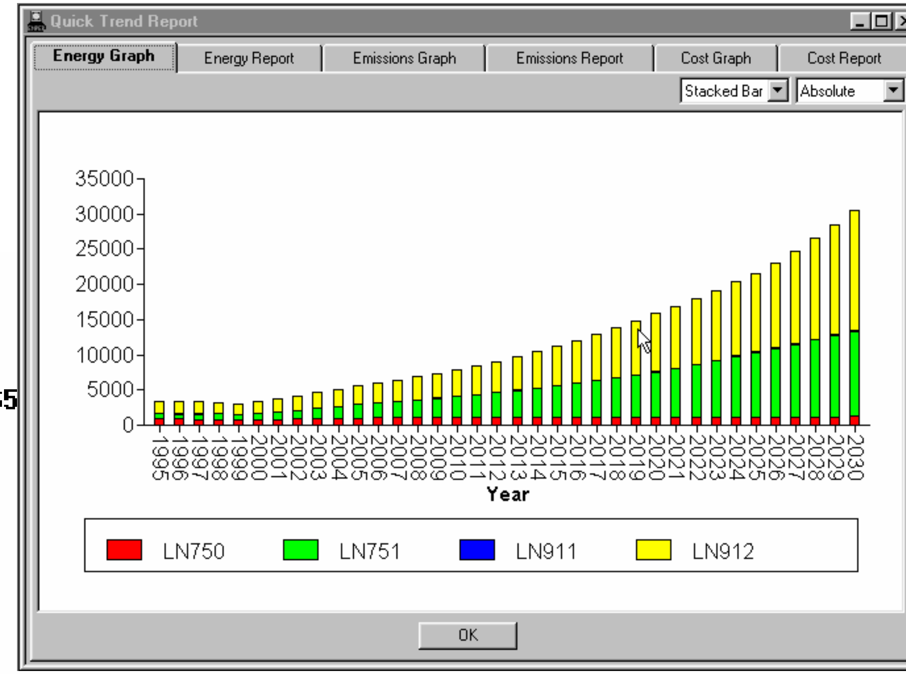
All Input Parameters Can be Changed Over Time

- **Annual changes are optional**
- **Input data remains constant until the year you enter a new value**
- **Please note: Price projections for resources and demand growth rates for demand nodes are different (they are not special events)**

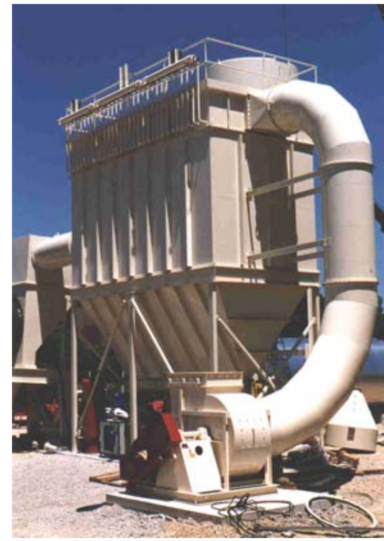


Results Can be Viewed Interactively for Individual Network Components





BALANCE Uses a Standard Methodology to Determine the Uncontrolled and Controlled Source Emissions



Uncontrolled Emissions = Fuel Consumption x Emission Factor x Chemical Scale

Controlled Emissions = Uncontrolled Emissions x (100 - Control Efficiency) / 100

Emissions Are Calculated and Reported by Node for any Pollutant the User Specifies

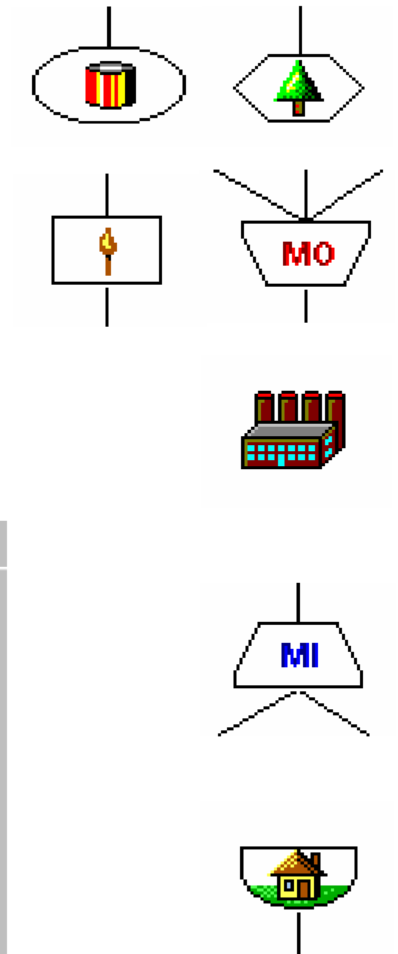
Run Parameters | Pollutants | Pollution Controls | Output Codes | Non-electric Units | Electric Units

Name	Abbreviation	Chemical Scale
Methane	CH4	
Carbon Dioxide	CO2	Carbon
Nitrous Oxides	N2O	
Non Methane Total Organic Compounds	NMTOC	
Nitrogen Oxides	NOX	
Particulate Matter Total	PM	Ash
Sulfur Dioxide	SO2	Sulfur
Carbon Monoxide	CO	

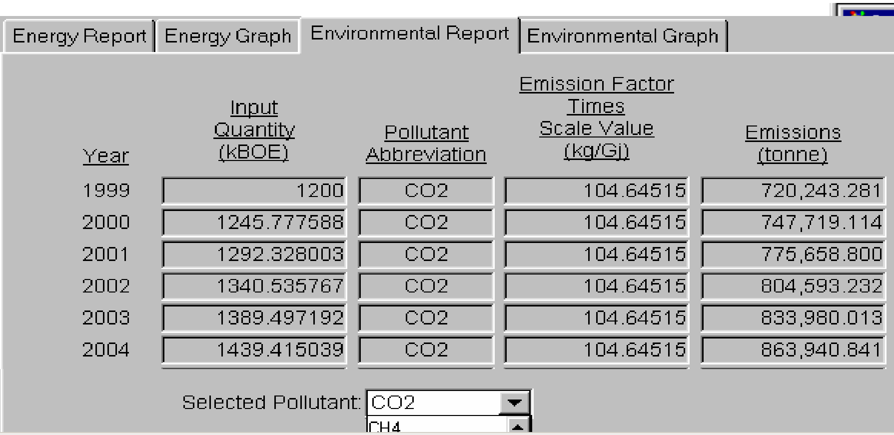
OK | Cancel | Add | Delete

Technical Properties | Economic Properties | Emissions Properties | Control Properties

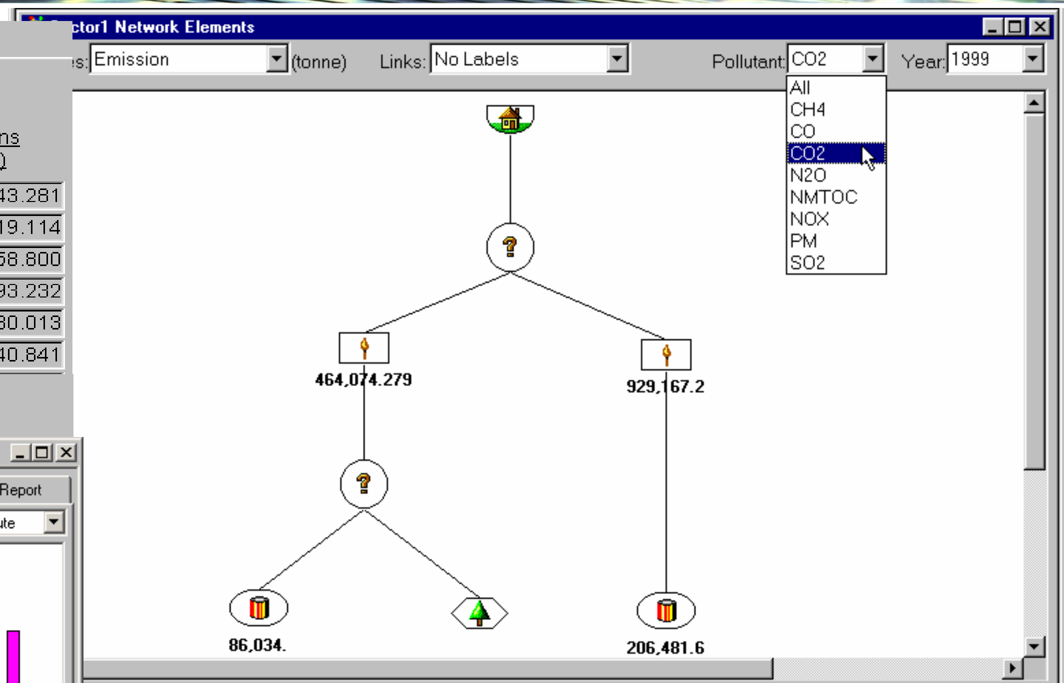
Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/Gj)	Chemical Scale	Scale Value (%)	Emissions Tax ($/tonne)
1999	CH4	0.001			
	CO2	1.349	Carbon	77.60	20.00
	N2O	0.002			
	NMTOC	0.001			
	NOX	0.399			
	PM	0.184	Ash	17.50	
	SO2	0.698	Sulfur	4.50	100.00

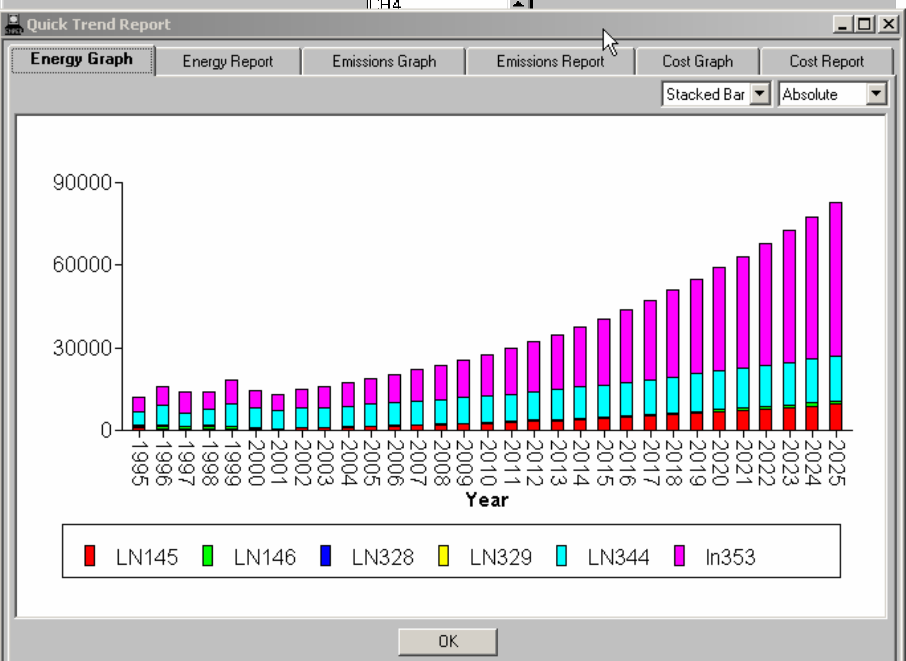


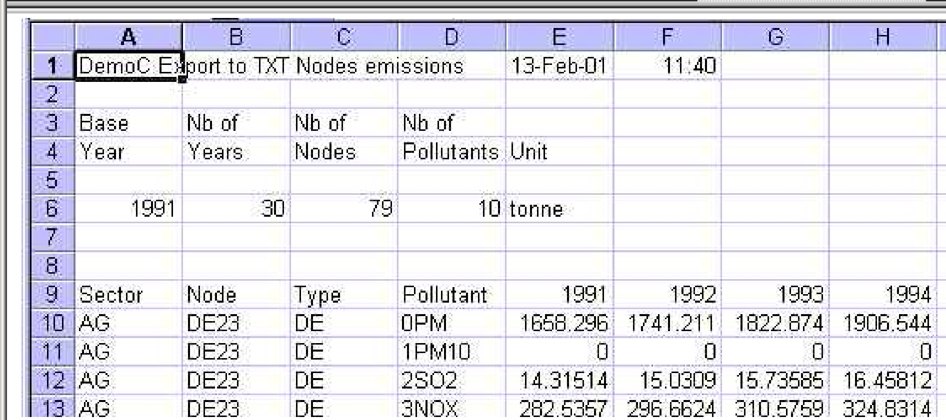
Environmental Results Can be Viewed Directly in the Network, in Tables, Simple Graphs, or Exported to EXCEL



Year	Input Quantity (kBOE)	Pollutant Abbreviation	Emission Factor Times Scale Value (kg/GJ)	Emissions (tonne)
1999	1200	CO2	104.64515	720,243.281
2000	1245.777588	CO2	104.64515	747,719.114
2001	1292.328003	CO2	104.64515	775,658.800
2002	1340.535767	CO2	104.64515	804,593.232
2003	1389.497192	CO2	104.64515	833,980.013
2004	1439.415039	CO2	104.64515	863,940.841

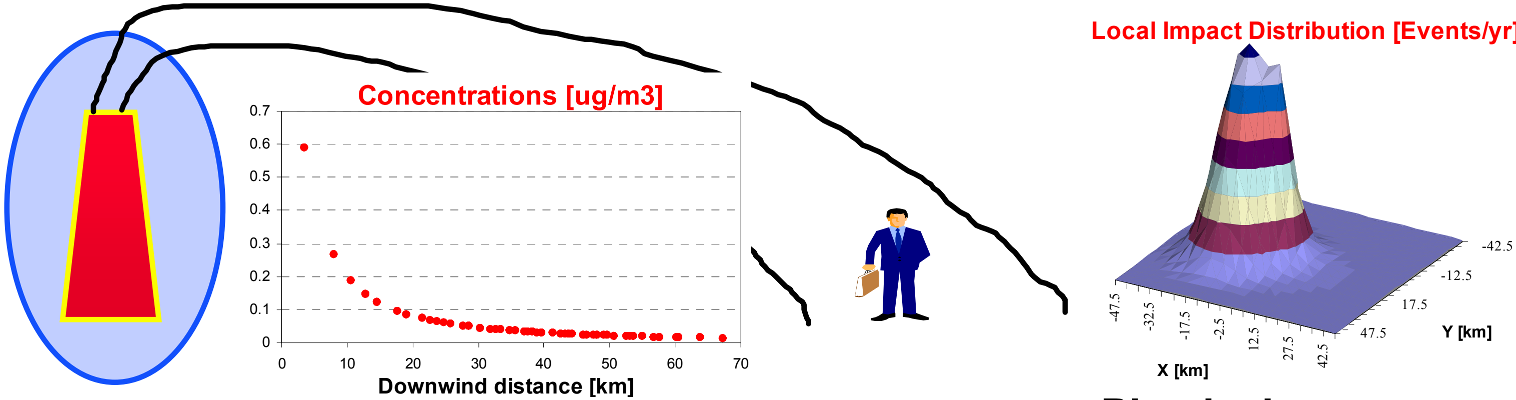






	A	B	C	D	E	F	G	H
1	DemoC Export to TXT Nodes emissions				13-Feb-01	11:40		
2								
3	Base	Nb of	Nb of	Nb of				
4	Year	Years	Nodes	Pollutants	Unit			
5								
6	1991	30	79	10	tonne			
7								
8								
9	Sector	Node	Type	Pollutant	1991	1992	1993	1994
10	AG	DE23	DE	0PM	1658.296	1741.211	1822.874	1906.544
11	AG	DE23	DE	1PM10	0	0	0	0
12	AG	DE23	DE	2SO2	14.31514	15.0309	15.73585	16.45812
13	AG	DE23	DE	3NOX	282.5357	296.6624	310.5759	324.8314

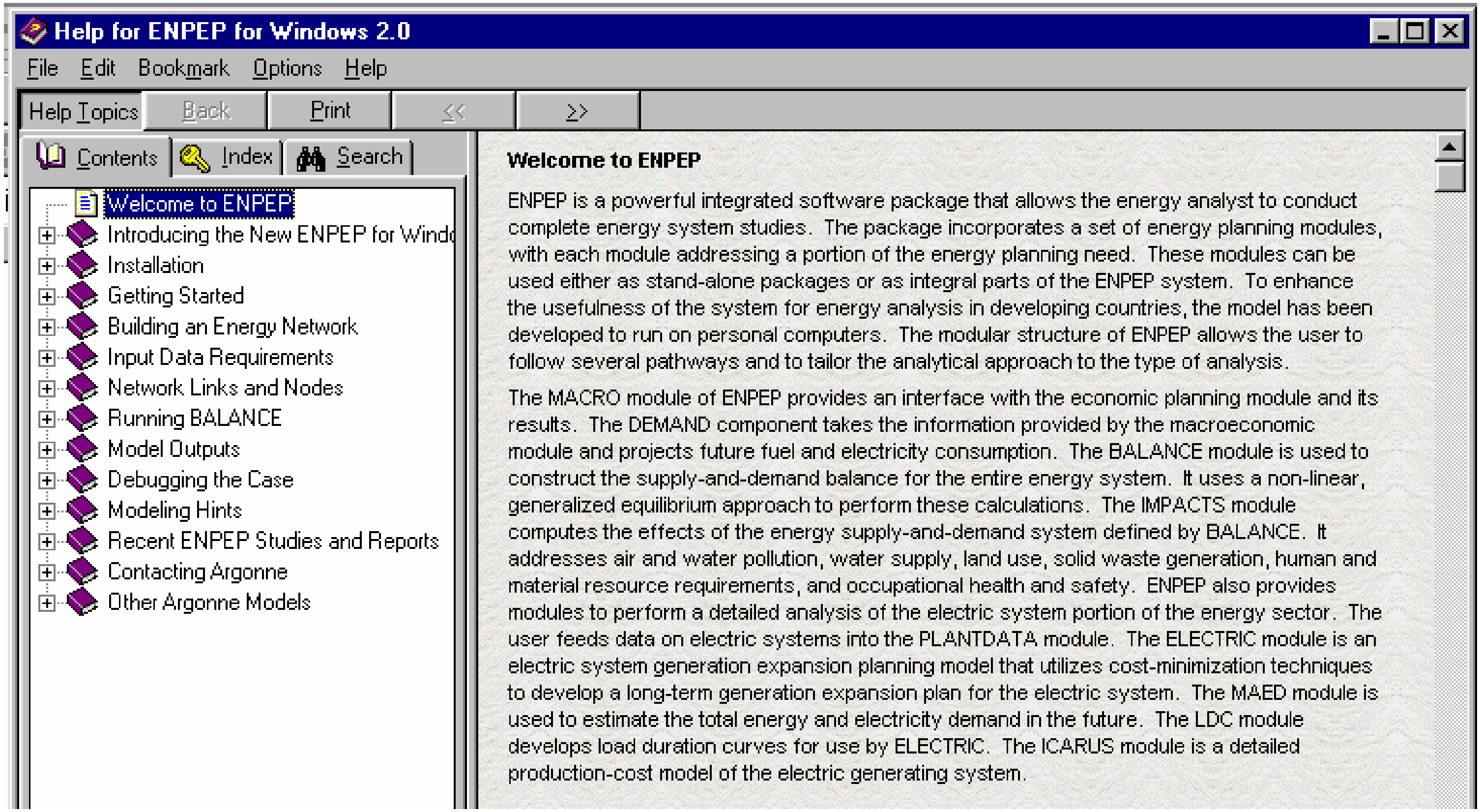
The New SIMPACTS Model Extends ENPEP's Emissions Calculations and Allows a Quick Analysis of Environmental Externalities



Source Emissions → **Transport Dispersion** → **Exposure of People & Ecosystems** → **Physical Impacts on Health and Environment** → **Valuation**

ENPEP (Source Emissions) ⟷ **SIMPACTS** (Transport Dispersion to Valuation)

A Help System is Available to Provide Online Support



Note: The help system is still under construction. Content will change and not all topics may be available at this time.

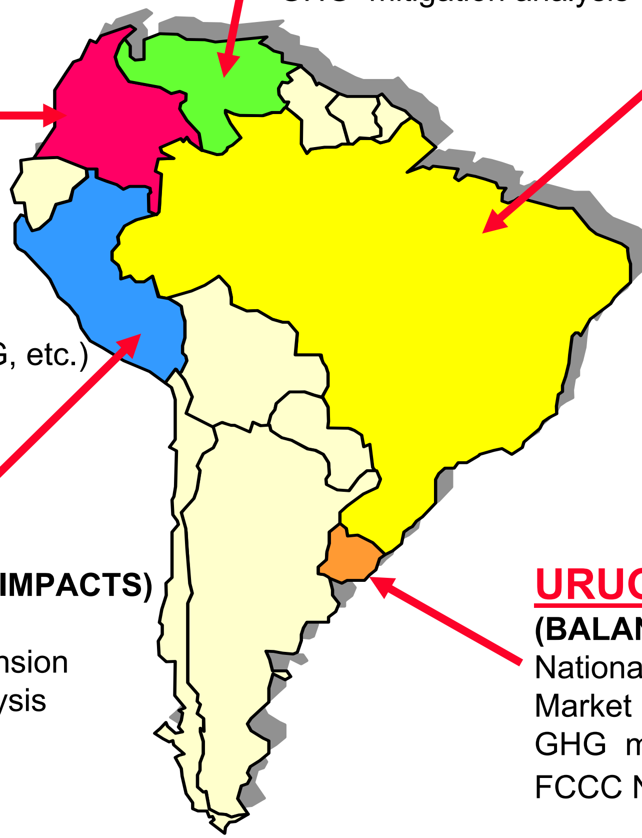
ENPEP is Used by Energy and Environmental Experts Worldwide to Analyze a Variety of Critical Issues

- **Electric system analysis**
  - expansion analysis, demand side management
  - optimal hydro/thermal dispatch ($, environment)
  - deregulation, independent power producers, power market studies, interconnection studies, etc.

- **Total energy system**
  - overall energy sector development strategies
  - natural gas market analysis
  - energy conservation+efficiency

- **Environmental analysis**
  - emissions projections for PM, SO_2, NO_X, etc.
  - emissions reduction strategies for PM, SO_2 and NO_X
  - emissions trading for SO_2 and CO_2 (cap and trade)
  - GHG mitigation studies and Kyoto Mechanisms
  - waste generation, land use, water pollution

Current/Recent ENPEP Applications in South America



VENEZUELA

(WASP, BALANCE, IMPACTS)

National energy analysis

GHG mitigation analysis

COLOMBIA

(MAED, WASP, BALANCE, IMPACTS, VALORAGUA)

National energy analysis

Natural gas expansion

Electric system development

Air pollution (PM, SOX, NOX, GHG, etc.)

PM + SOX control cost analysis

BRAZIL

(WASP, BALANCE, VALORAGUA, IMPACTS)

State energy analysis

State electric system development

Air pollution analysis

Land use analysis

Decision analysis

PERU

(WASP, BALANCE, IMPACTS)

Load forecasting

Electric system expansion

National energy analysis

Air pollution analysis

GHG mitigation

URUGUAY

(BALANCE, IMPACTS)

National energy analysis

Market penetration of natural gas

GHG mitigation analysis

FCCC Nat Com (submitted)

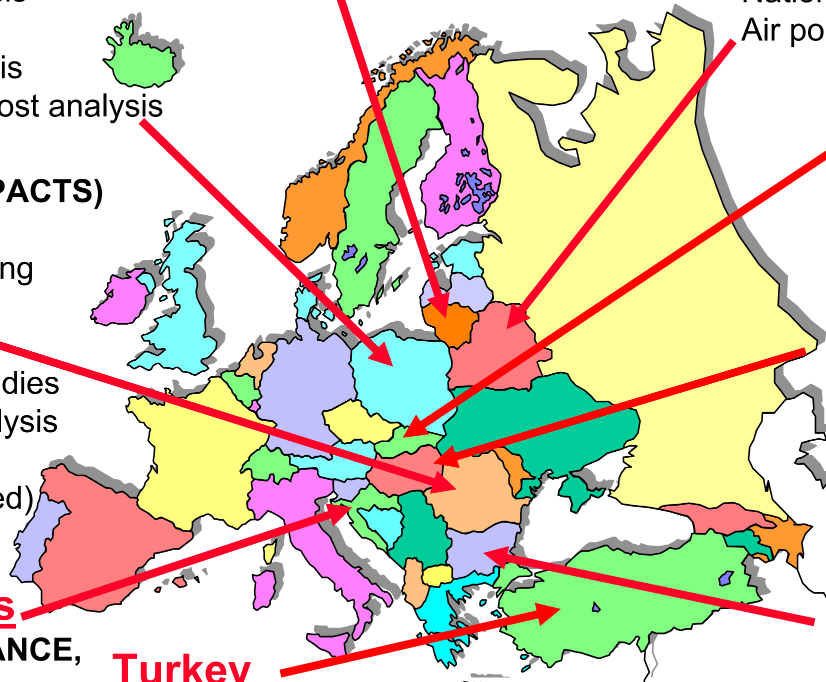
Current/Recent ENPEP Applications in Eastern Europe

Poland
(MAED, WASP, BALANCE, IMPACTS)
Deregulated power market analysis
National energy analysis
Air pollution analysis
GHG mitigation analysis
PM and SOX control cost analysis

Lithuania
(WASP, MAED)
Electric system analysis

Belarus
(WASP, BALANCE, IMPACTS)
Electric system expansion
National energy analysis
Air pollution analysis

Romania
(WASP, BALANCE, IMPACTS)
National energy analysis
Energy sector restructuring
Natural gas imports
Rehabilitation, IPPs
Removal of energy subsidies
Air & water pollution analysis
GHG mitigation analysis
FCCC NatCom (submitted)
Waste generation



Slovakia
(BALANCE, IMPACTS)
National energy analysis
GHG mitigation analysis
FCCC Nat Com (submitted)
Joint implementation

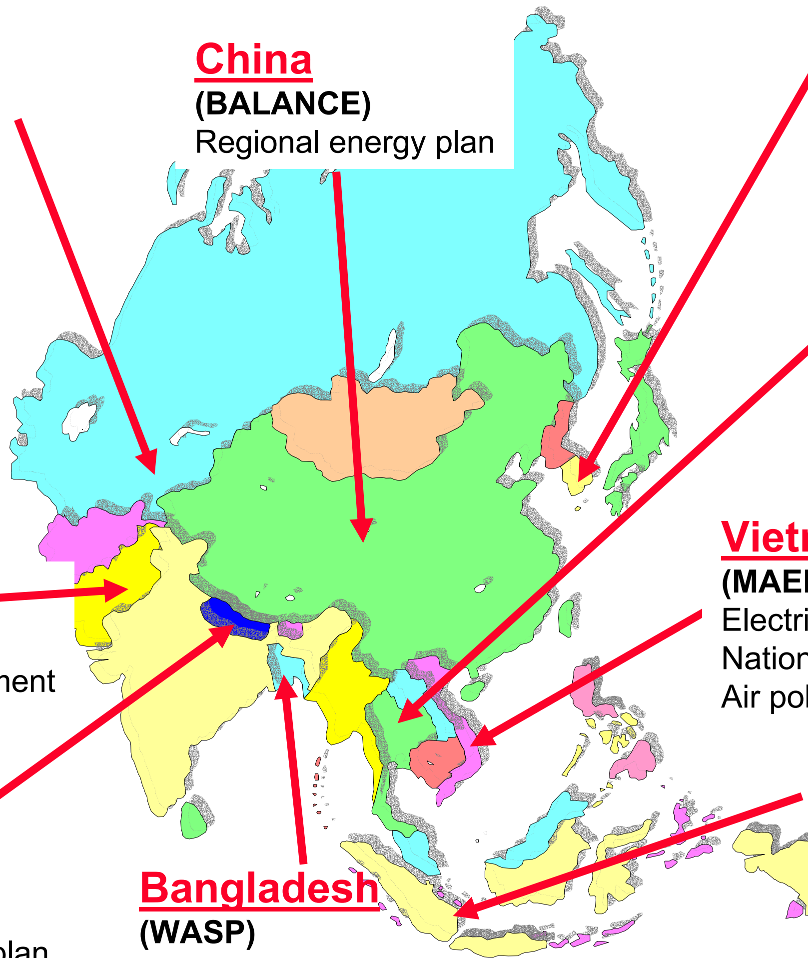
Hungary
(WASP, BALANCE, IMPACTS)
Electric sector expansion
National energy analysis
GHG mitigation analysis
IPP Bid Evaluation

Croatia+Balkans
(MAED, WASP, BALANCE, IMPACTS)
National energy plan
Electric system expansion
Air pollution analysis
IPP+Interconnection study

Turkey
(WASP, ICARUS, BALANCE, IMPACTS, etc.)
National energy plan
Electric sector dispatch and expansion
Privatization, Environmental assessments

Bulgaria
(WASP, BALANCE, IMPACTS)
National energy plan
Electric system development
GHG mitigation analysis
FCCC Nat Com submitted

Current/Recent ENPEP Applications in Asia



Kazakstan
(BALANCE, IMPACTS)
National energy plan
GHG mitigation analysis

China
(BALANCE)
Regional energy plan

South Korea
(WASP)
Electric system development
GHG mitigation analysis
FCCC Nat Com (submitted)

Thailand
(BALANCE, IMPACTS)
National energy plan
GHG mitigation analysis

Pakistan
(WASP)
Electric system development

Vietnam
(MAED, WASP, IMPACTS, BALANCE)
Electric system development
National energy plan
Air pollution analysis

Indonesia
(WASP, BALANCE, IMPACTS)
Electric system analysis
National energy plan
Air pollution analysis

Nepal
(WASP)
National energy plan
GHG mitigation analysis

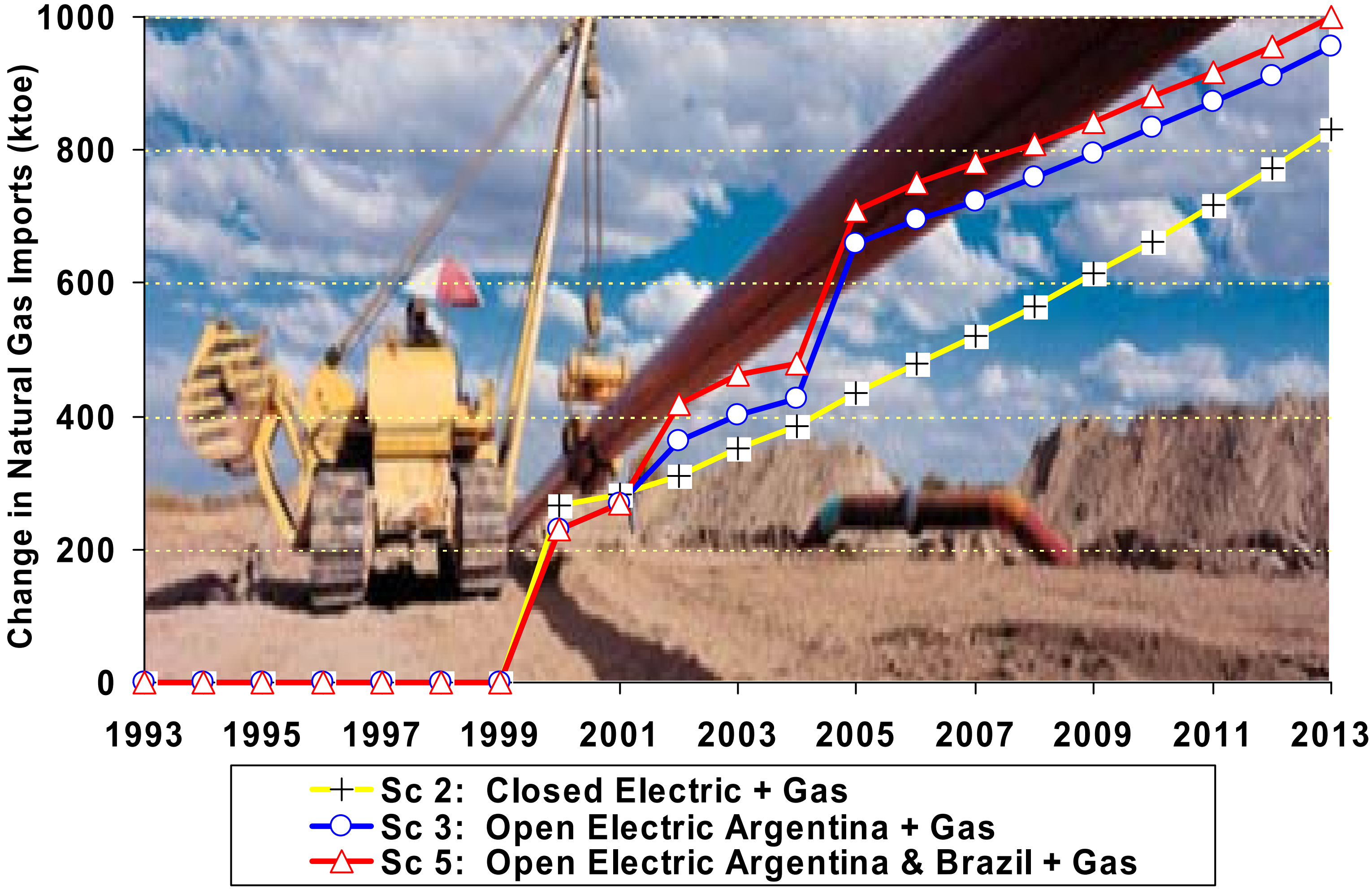
Bangladesh
(WASP)
IPP Evaluation

ANL and Local Experts Used ENPEP to Analyze Natural Gas and Electricity Issues in Uruguay

- **Overall energy sector development strategy in light of increasing regional integration**
- **Uruguay's energy supply system is undergoing change (MERCOSUR, natural gas imports, potential increase in electricity connections with other countries, energy sector reform, etc.)**

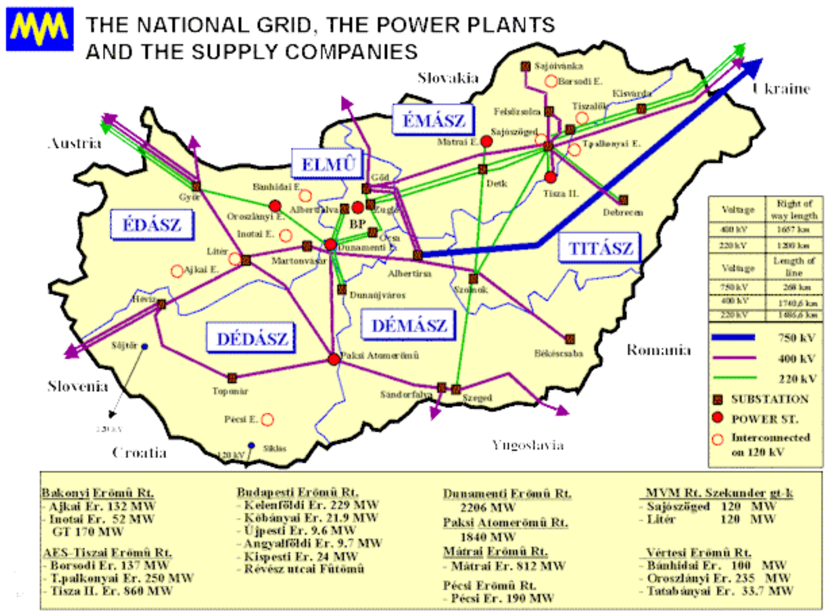
- **For a total of six scenarios, analyze fuel substitution trends due to gas imports and increased electricity interties, and project future market penetration of natural gas by sector**
- **DIS collaborated with a team of local energy experts from the Presidential Planning Office (OPP), Ministry of Energy (MoE), National Energy Office (DNE), Electric Utility (UTE), Oil Refinery (ANCAP), and Gas Company**
- **Project sponsored by The World Bank**

Uruguay's Projected Natural Gas Imports Are Highest in an Open Regional Electricity Market



ANL Used ENPEP to Assist the Hungarian Power Companies in Evaluating IPP Bids

- The Hungarian Power Companies (MVMRt) were recently restructured from a state-owned vertically integrated utility into a transmission company; generation is owned by private (domestic and foreign) companies; 6 regional private distribution companies
- MVMRt determined additional power generation capacity is needed; MVMRt issued a tender in 1997 and received 80 initial responses



- MVMRt contracted Argonne to develop a methodology for evaluating the IPP bids and to audit the evaluation process
- MVMRt signed two long-term PPA contracts with operators of gas-fired combined cycle combustion turbines worth $1.3 billion
- Announcement can be found at http://www.mvm.hu/angol/angkapac.html

Technical Experts from Poland Used ENPEP to Analyze the Requirements of the Kyoto Protocol

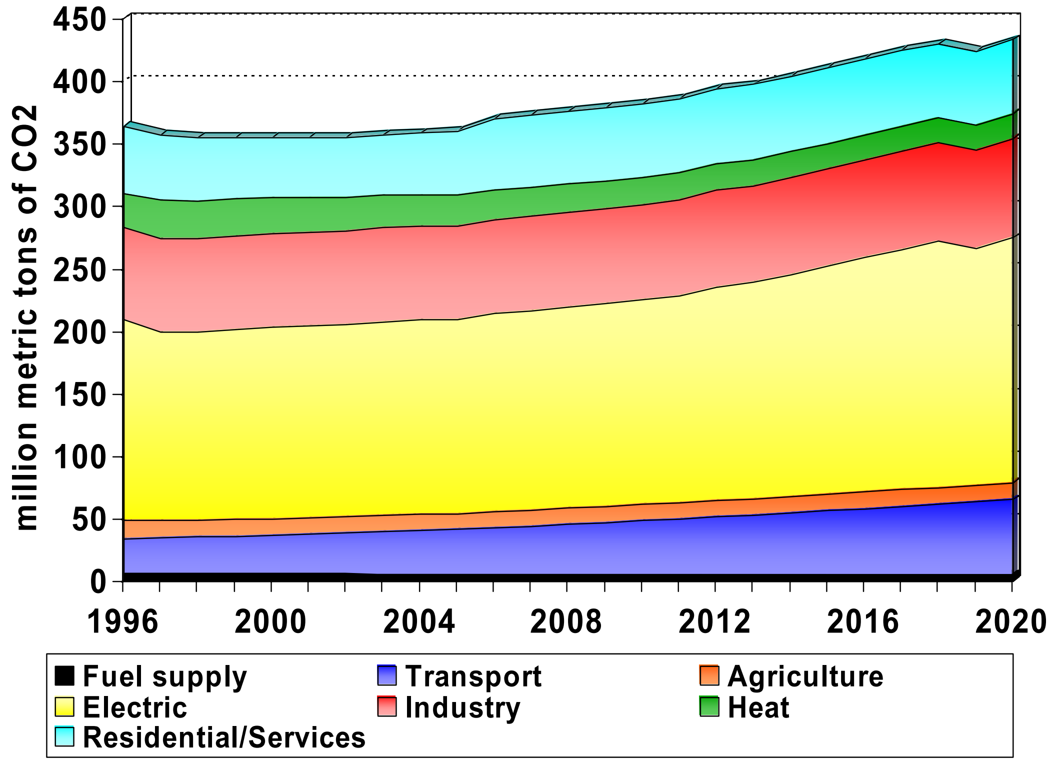
Poland's Power Sector Remains Largest Source of CO_2 Emissions under the Baseline Scenario

- Total CO_2 emissions are projected to increase from 363 million metric tons (1996) to 433 million metric tons (2020); the growth in emissions comes from the electric sector and the transportation sector

- Share of power sector remains fairly constant and is still 45% by 2020

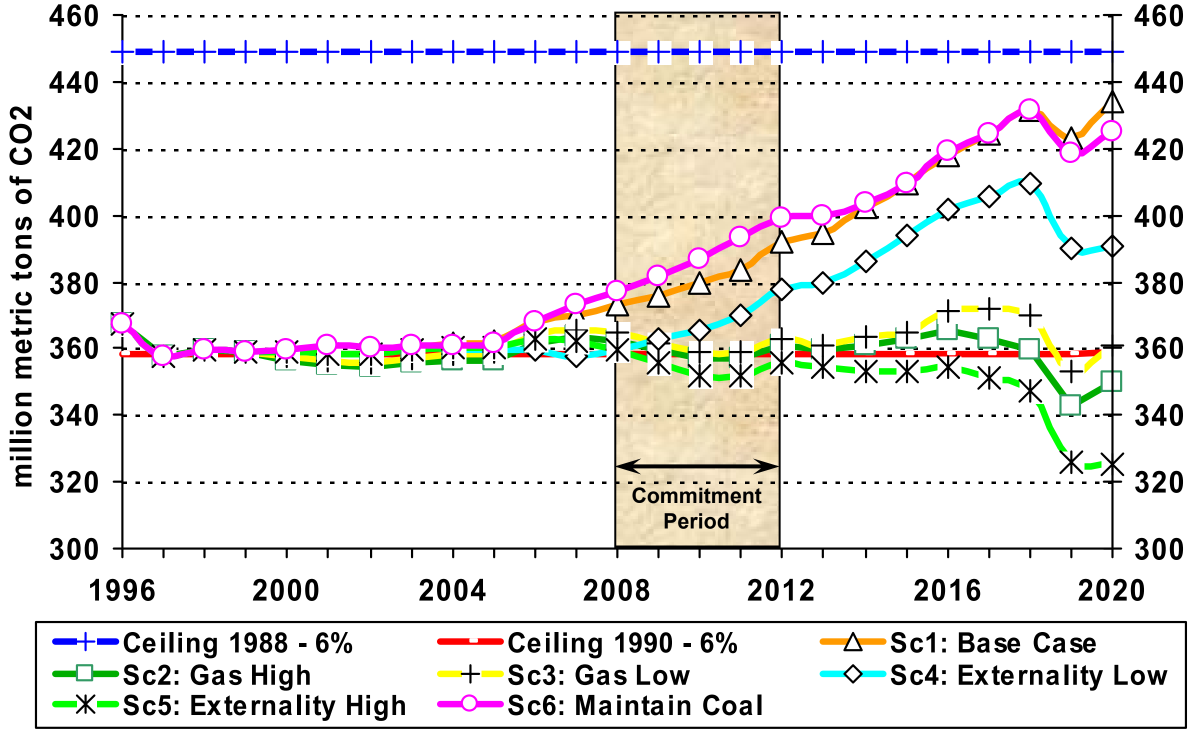
- Transport sector emissions grow quickly with its share increasing from 8% (1996) to 14% (2020)

- The shares of the other sectors are all projected to decrease



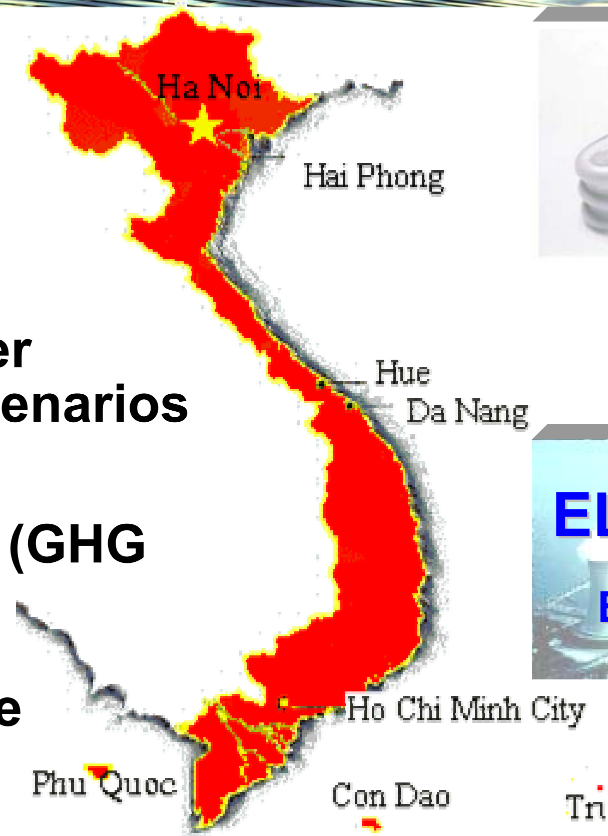
Meeting Kyoto Requirements Will Depend on the Choice of Base Year for Poland

- As an Economy-in-Transition, Poland has the flexibility to choose the base year for its CO_2 reduction commitments (1988 rather than 1990)
- If Poland had to reduce its CO_2 emissions to 6% below 1990 levels, only one scenario would be consistently below the limits
- All scenarios are projected to meet the limit of 449 million tons (1988 minus 6%)
- CO_2 reduction by 2020 of up to 109 million tons, (or 25% below the baseline scenario
- Nuclear may cut CO_2 emissions by up to 50 million tons

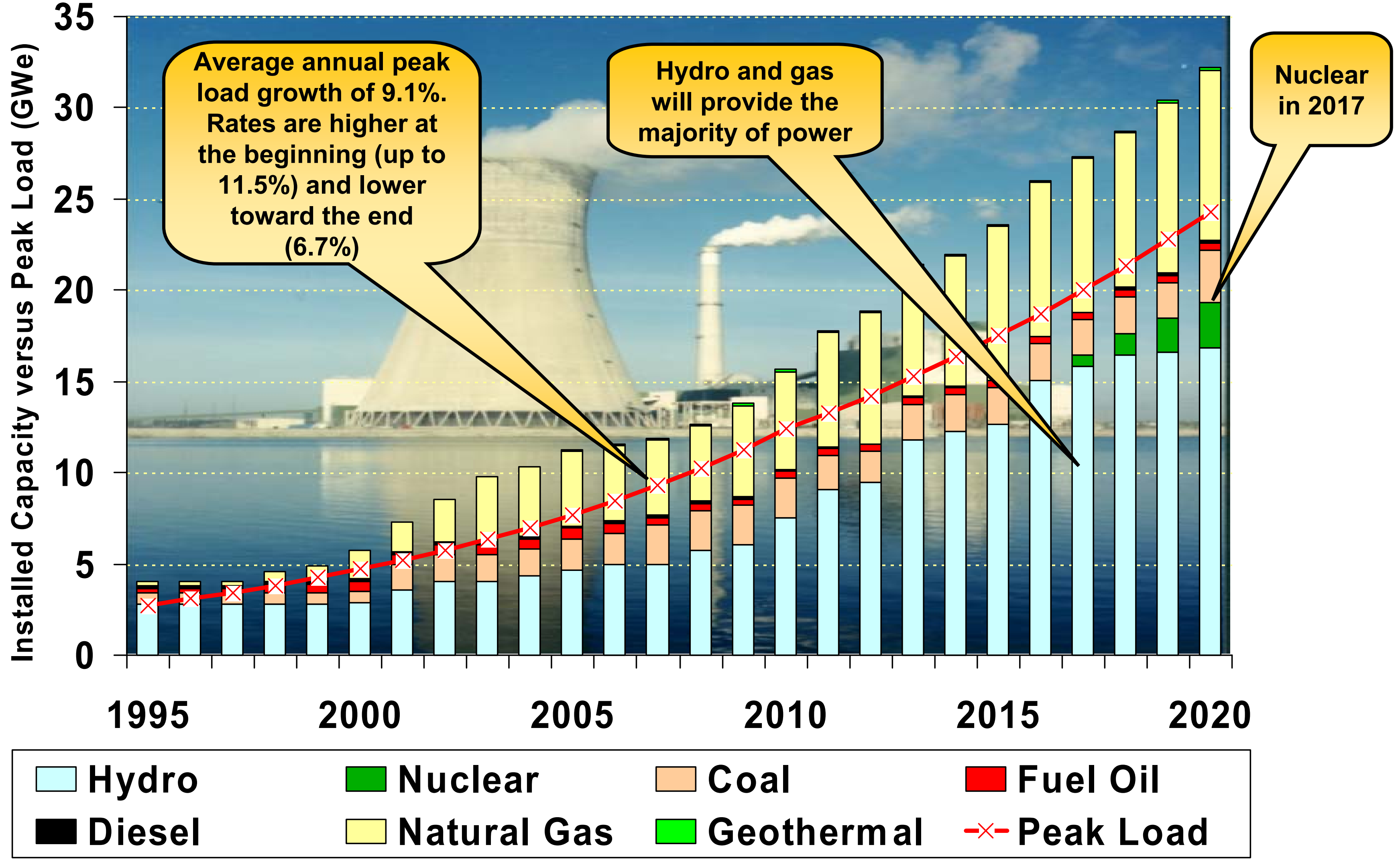


Technical Experts in Vietnam Used ENPEP to Project Emissions from Power Generation

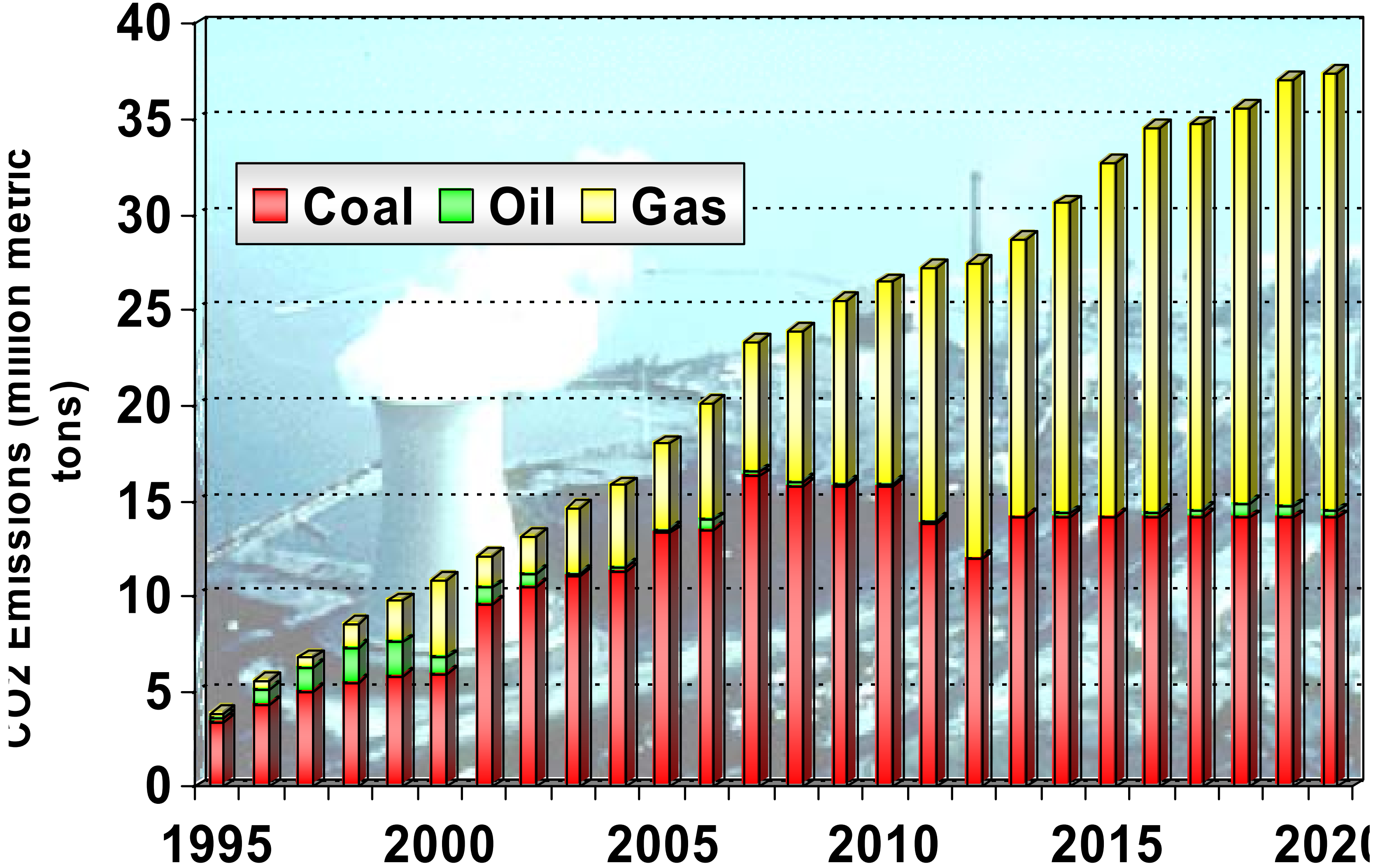
- ***MAED*** **was used to obtain the load forecast; generates seasonal load duration curves required by ELECTRIC (WASP)**
- ***ELECTRIC (WASP)*** **was used to develop the long-term electric power system expansion under several scenarios**
- ***IMPACTS*** **was used to calculate the emissions of a variety of pollutants (GHG and non-GHG) and to estimate the mitigation cost for reduction of particulate matter and sulfur dioxide**
- **Team composed of experts from Vietnam Atomic Energy Commission – Institute of Nuclear Science and Technique**
- **Project supported by IAEA and US State Department**



Vietnam's Economy is Projected to Continue its Rapid Growth Requiring Substantial Power System Expansion

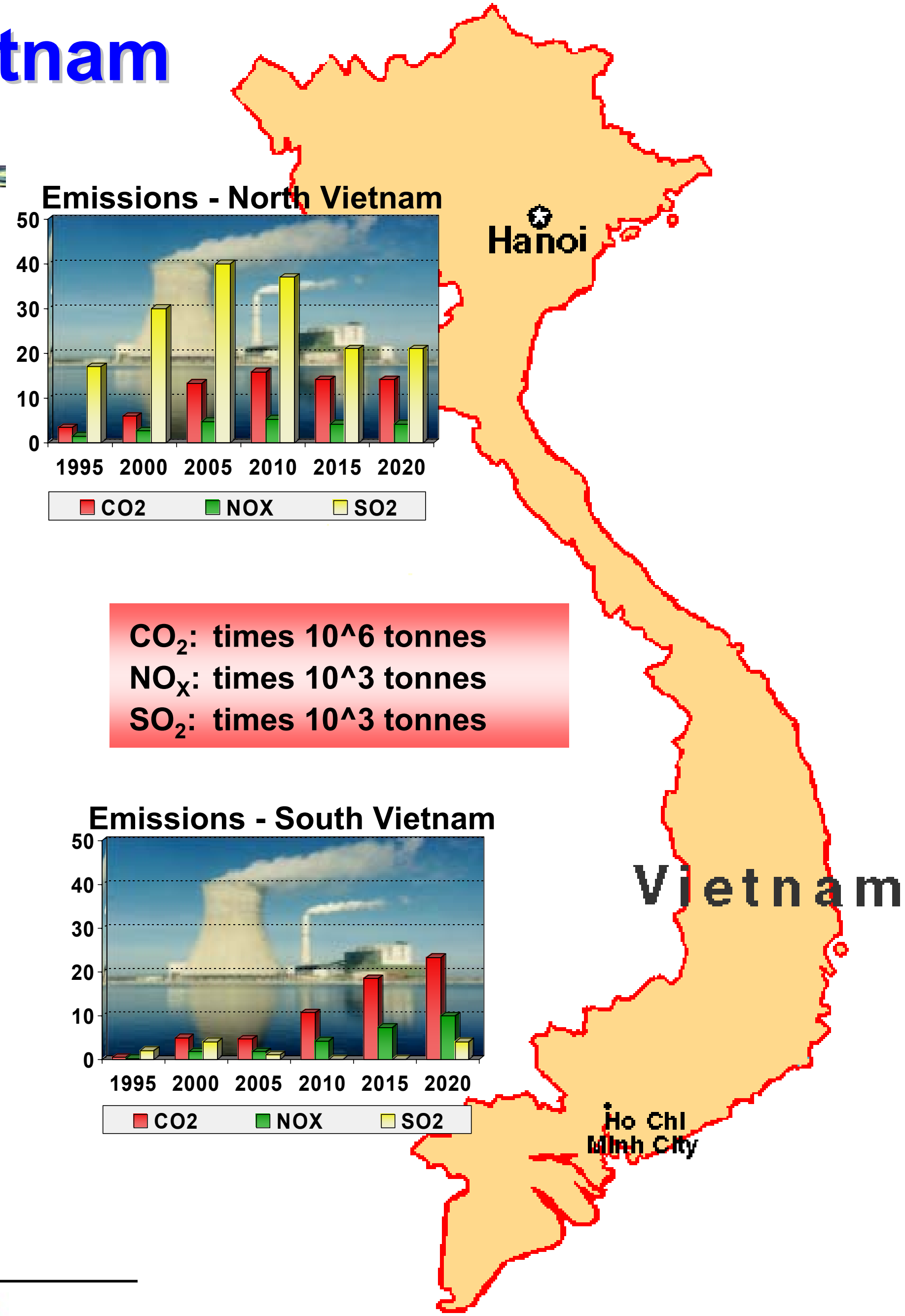


Vietnam's CO_2 Emissions from Power Generation are Projected to Grow Significantly

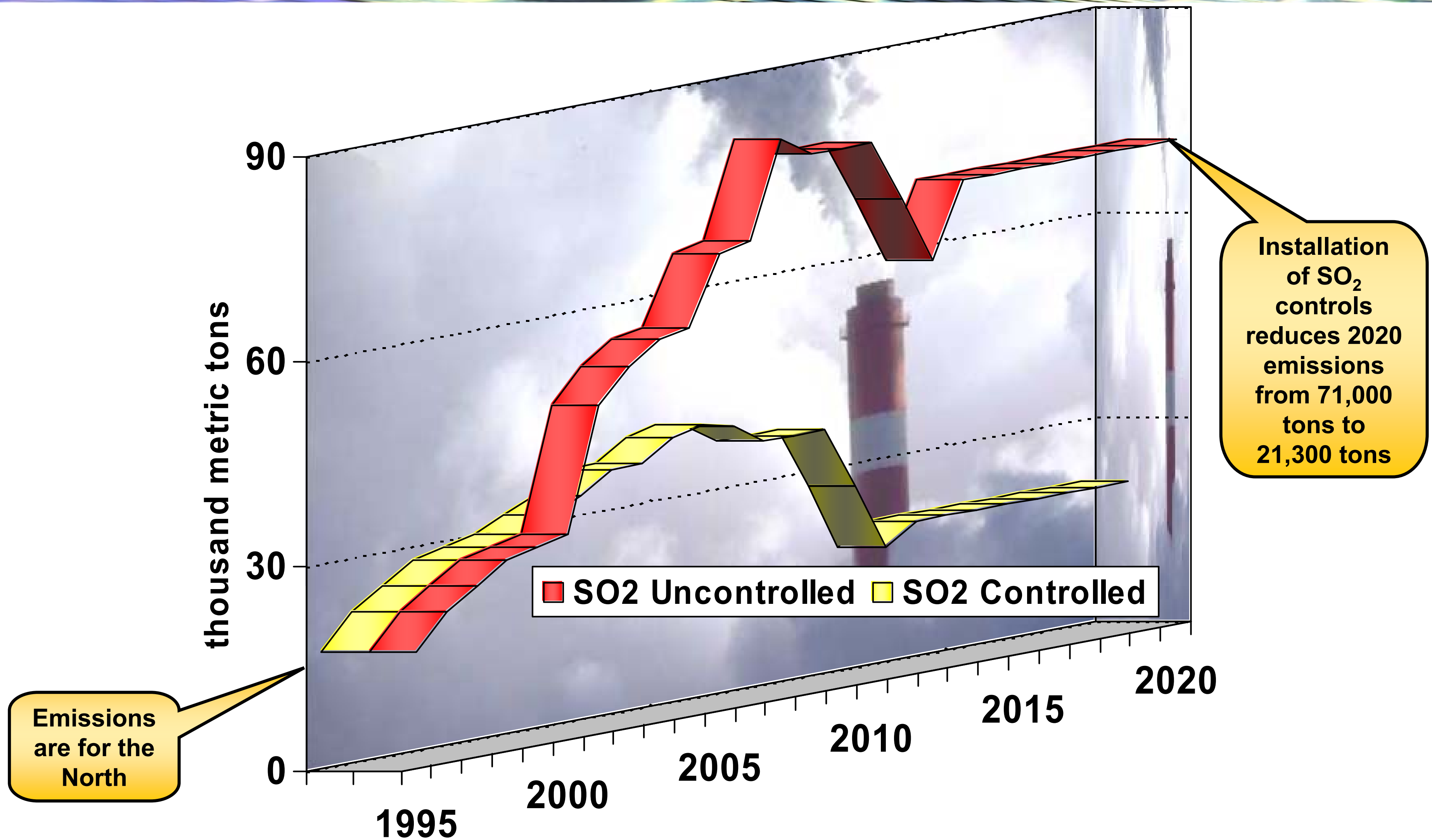


Emissions by Region in Vietnam

- **Most of the current and new coal units are located in the northern region where Vietnam's coal resources can be found**
- **83% of SO_2 emissions are in the north**
- **After 2007, many existing and inefficient coal units retire**
- **Vietnam's oil and gas resources are mostly in the south where most of the new gas-fired units are expected to be constructed**
- **By 2020, about 62% of CO_2 and 70% of NO_X emissions are generated by gas-fired units in the south**



Complying with Vietnamese Air Pollution Rules Reduces 2020 SO_2 Emissions by 50,000 Tons Annually (70%)



Vietnam's Emission Abatement Costs for PM and SO_2 are Significant